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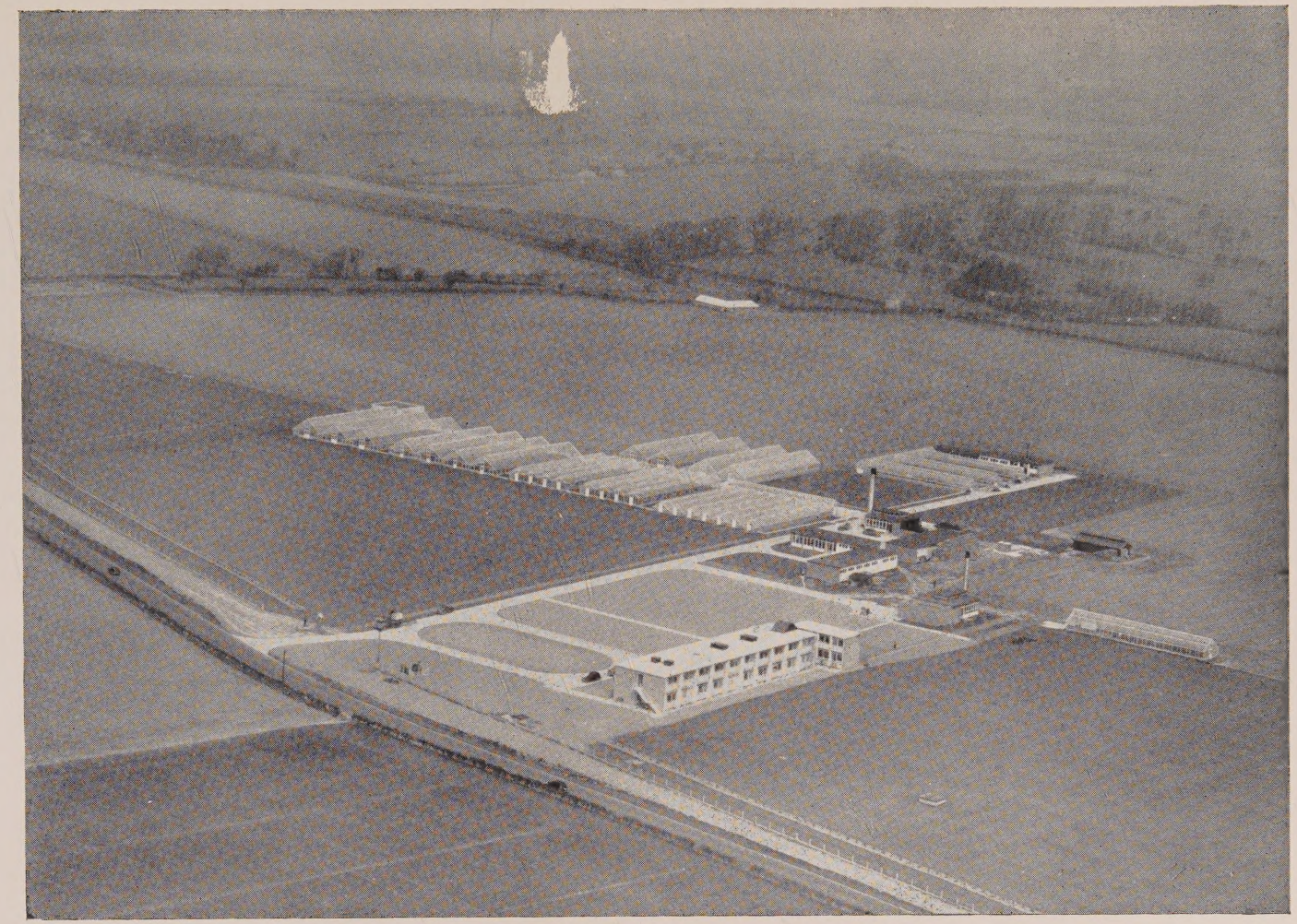

The Glasshouse Crops Research Institute from the air

The Laboratories

GLASSHOUSE CROPS RESEARCH INSTITUTE

ANNUAL REPORT

1954-1955

LITTLEHAMPTON . SUSSEX

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Glasshouse Crops Research Institute

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Dr. W. F. BEWLEY, C.B.E., V.H.M.

It would not be fitting to let this report appear without drawing attention to the fact that it is the last to be prepared by Dr. W. F. Bewley, the Institute's first Director. Dr. Bewley retired from the directorship at the end of September, 1956, after a lifetime of service to the glasshouse industry. He had previously been in charge of the Experimental and Research Station at Cheshunt for over thirty years, and the present report bears, unmistakably, the stamp of the long series of reports which went out from that station.

Dr. Bewley joined the staff of the Cheshunt station in 1919 but was soon to be appointed to the Directorship, and from 1921 until the station was closed down in 1955 he controlled its affairs with so much success that the name of Cheshunt has become famous the world over. The reasons which led to the closing down of the Cheshunt station, and the steps which were taken to find a new site where its activities could be continued and developed on a more adequate scale, are given in Dr. Bewley's own words in the introduction to this report. The new Institute is a monument to him, and all who have seen it must feel satisfied that it has been worthily endowed to continue the great traditions of Cheshunt and to undertake the more intensive research that the present-day problems of the glasshouse industry demand. The industry owes a great debt to Dr. Bewley for the tremendously hard work that has gone into the initial planning of the new Institute and for carrying out with so little interruption to the research programme the enormously complicated arrangements involved in the transfer from Cheshunt. Although there is much development still to come the new Institute has been very soundly established for the task that lies ahead of it, and all growers and others interested in its work may feel confident that is has a bright future, thanks to the wisdom and foresight of Dr. Bewley.

Dr. Bewley, whose portrait is published opposite, is so well known to most of those into whose hands this report will fall that a personal appreciation would be superfluous. His genial presence will be greatly missed at the Institute, but we are happy to know that he is still living near us. The very best wishes of his successor and of his former colleagues go with him in his retirement.

Introduction

It is a pleasure to present this first report of the Glasshouse Crops Research Institute, now established on a site of 100 acres to the north of the Worthing Road, Littlehampton.

The idea of removing the Experimental and Research Station at Cheshunt to a new site was first conceived by the late Dr. Topley when he was Secretary of the Agricultural Research Council prior to the Second World War. Unfortunately, the outbreak of hostilities put an end to any development of this project and it was not until peace returned that the Council decided to proceed with the idea.

By this time facilities at the Cheshunt Station had become totally inadequate. Three times during the war it had been seriously damaged by enemy action. On September 23rd, 1940, a land mine dropped by parachute fell to earth some 200 yards to the west. This blew out most of the laboratory windows and also glass out of the glasshouses besides shaking the houses themselves very badly and pushing the mushroom shed off its foundations. The glasshouses were repaired and the laboratories given First Aid treatment.

Then on May 8th, 1941, 5,000 incendiary bombs were scattered over the Research Station premises, the Director's house and also dwelling houses in the immediate vicinity, damaging both the glasshouses and the heating system; pipes being cracked by the intense heat of bombs in contact with them. Only prompt action saved the crops. Lastly, in July, 1944, came the third attack, when a flying bomb (VI), dropped some 150 yards to the east causing much damage to surrounding property. Once again practically all the glass in the glasshouses was broken and most of the laboratory windows fell out. Apparatus and materials inside the laboratory fared badly and much was destroyed.

All this disturbance shook the glasshouses so severely that they could not be repaired. Little could be done, apart from shoring them up with heavy timbers to keep them erect until a new station could be built.

Difficulties were further increased by the fact that new additions to the staff, made after the end of the war to cope with new problems, rendered the buildings very congested and some kind of expansion had become urgent.

The story of the long search, and the hundreds of sites inspected by the Director and his colleagues is no longer important, although at one time it seemed as if the ideal situation would never be found. Ultimately, with the assistance of a committee of south country growers representing East and West Sussex, Surrey and Hampshire, a number of sites were submitted to the authorities. Finally the Ministry of Agriculture, acting on the advice of the Agricultural Research Council and with Treasury permission, purchased a site of approximately 100 acres behind Littlehampton, and leased it a to a new company to be known as the Glasshouse Crops Research Institute.

This necessitated winding up the old Nursery and Market Garden Industries Development Society Limited, which was originally registered under the Friendly Society's Act in 1913. This was duly carried out by two liquidators—Mr. L. Madsen and Mr. George Cobley, who were President and Auditor respectively of the Cheshunt Station at the time. In due course the buildings at Cheshunt were sold and the proceeds handed over to the new Institute to be used in capital expenditure.

Preliminary plans for the new research centre were first designed and agreed by the Committee of the Cheshunt Station and then discussed with a firm of architects, Messrs. Cowper and Poole.

Armed with these plans Major Cowper, with the approval of the Agricultural Research Council, Ministry of Agriculture and the Treasury, drew up a very comprehensive Master Scheme for developing the new site by stages so that all future development could proceed smoothly according to a preconceived plan.

(a) Development of the Site.

By the beginning of 1953, the main roads and services had been finished sufficiently to commence building the first glasshouses approved by the Agricultural Research Council and the Ministry of Agriculture. These amounted to five blocks in all covering one glasshouse acre and also a propagation unit. The five blocks followed one another from East to West along the south side of a road which branched in a westerly direction from the main central road.

The most easterly block A, for cucumbers and plants requiring similar conditions, consists of seven houses each 104 feet long and 14½ feet wide, connected across the north ends by means of a glass corridor 6 feet wide to provide protection from northerly winds. There is one fixed divisional wall separating four houses from three houses. The block covers approximately 0.25 acres.

To the west of block A, follow naturally first block B and then block C; identical so far as construction is concerned each covers about 0.125 acres and consists of four houses each 110 feet long and 14½ feet wide. They are of the type known to growers as "aeroplane" houses, owing to the high gutters, which in this case are about seven feet above ground at the highest point.

The purpose of these two small blocks is to act as suitable houses in which crops can be studied by means of very accurate statistical methods.

The fourth block—D— of the "Vinery" type, was intended mainly for tomatoes. It contains four houses each 110 feet long and 29 feet wide.

Three modern carnation houses form Block E. Each house is 110 feet long and 31 feet wide. The gutters are seven feet and the ridges about 16 feet high.

The future development of the experimental nursery provides for a second acre of glasshouses to be erected in blocks in a line parallel to and north of the first line of five blocks.

The eastern end of this second line is already taken up with the propagation block and the four houses (in two pairs) provided by the Tomato and Cucumber Marketing Board for the purpose of breeding the ideal tomato.

When funds are provided this line of houses will be continued by erecting a quarter acre block for pot plants, another for roses and plants requiring similar conditions and then finally a block for the further investigation of soil warming.

The original plan was to provide a total of four acres of glasshouses and in view of the outstanding importance of such factors as light, temperature and humidity it was proposed to devote the third and fouth acres of glass to the provision of a number of single houses that could be set aside for these experiments. To investigate the effect of three different temperatures at three levels of light intensity would require 27 houses if the treatments are to be carried out in triplicate. Using houses 116 feet long and 29 feet wide like the individual houses in block D, the 27 houses would take up about two acres of glass.

A total equipment comprising the present seven blocks with the addition of three blocks for pot plants, roses and soil warming and also 27 single houses for plant climate research would give the scientists very reasonable facilities for their investigations and also provide in the first two acres of glasshouses a sufficient variety of good commercial houses in which to submit their discoveries to a final trial under commercial conditions before publishing their recommendations in a form that would be easily understood and applied by growers.

The heating as well as the construction of the first of the seven blocks of glasshouses conform to the best commercial practice of modern glasshouses and which must represent the majority of nurseries for many years to come.

A single boiler house has been provided for the boilers needed to heat two acres of glasshouses. In the first seven blocks of houses hot water is circulated slowly by electric pumps through 4 inch hot water pipes. Each block of houses is thermostatically controlled.

When new blocks for pot plants etc., are constructed, heating will be carried out by the rapid circulation of hot water in 1½ inch pipes. So, it will be possible to make a comparison between these two methods of heating.

Two boilers have been installed in a well-ventilated boiler house, which has two windows running the whole length of two sides to give plenty of light all round the apparatus, and is of sufficient size to accommodate another boiler. The boiler house floor is at ground level, and access to the house for repairs, ash removal, etc., is made easy by large doors.

Each boiler has an output of 2,400,000 B.T.U. per hour (total output of about 26,600 lineal feet of 4 inch piping). They are mild-steel welded "W" boilers, 81 inches long by 69 inches wide by 88 inches high by Charles Mc Neil Ltd., of Glasgow. It is anticipated that the two boilers will be capable of carrying the full load of two acres of glass, with a third boiler as reserve power for breakdown or cold weather when additional heat is required.

"Iron Fireman" underfeed stokers are fitted to each boiler so that cheap bituminous coal can be burnt. The stokers are of the bunker type, which brings the coal, below floor level, direct from the stack without any handling.

The stokers are controlled by a "Satchwell" compensator equipment which anticipates the outside weather conditions so as to give the amount of heat likely to be required. There is also a safety immersion thermostat to prevent boiling.

A 5 inch pump, driven by a 5 h.p. electric motor, circulates the water throughout the whole range of glasshouses. A duplicate set is also installed, together with a JAP petrol/paraffin engine which can be used if there is an electric power failure. Interchangeable pulleys are provided for the pump so that the output can be varied according to the number of glasshouses which require heating. The present maximum output is 330-gallons per minute, but it will be possible to raise this for the additional requirements when the second acre of glasshouses is ready. Six-inch flow and return mains run from the boiler house in trenches to the various blocks of glasshouses. Each block has its own set of valved mains, so that they are entirely independent of one another. This is essential, as the heat requirements of each block will vary, due to the varied crops to be grown, such as tomatoes, cucumbers, lettuce, carnations, pot plants, chrysanthemums, roses, grapes, etc. Each block is fitted with a "Satchwell" butterfly valve, which is controlled by an air thermostat to give an even heat at the required temperature.

The number of 4 inch pipes in each glasshouse follows conventional lines, but care has been taken in positioning the pipes so that they are best suited for the growth of the crop, and also to accommodate the largest possible number of plants.

The mains in trenches are lagged with "econite" sectional covering with weatherproof finish wired on and painted with bituminous paint. The boilers and piping in the boiler house are covered with "Eureka" magnesia/asbestos plastic composition and painted in varying colours for identification.

This heating apparatus was designed and installed by the Thames Bank Iron Company Limited, of Lodge Road, London, N.W.8, in conjunction with the Architect, J. B. F. Cowper, Esq., F.R.I.B.A., and the Director. In designing the apparatus, an attempt was made to keep the labour of maintenance

down to a minimum; to have flexibility and control of temperature and yet provide conditions suitable for the great variety of crops and requirements of research; to keep fuel costs down to the minimum; to keep the apparatus in line with commercial design within the range of growers; to let growers have the opportunity of seeing modern types of equipment, and above all, to meet the requirements of a research station.

It is not claimed that all these points have been achieved, as this was impossible in one form of apparatus, but it is hoped that when future glasshouses are erected further types of apparatus will be installed, bearing in mind steam, electricity, and high pressure hot water as mediums for heating; heat pumps, forced draught, oil firing, and chain grate stokers as sources of heat generation; smaller sized piping in glasshouses—to mention only a few of the future possibilities.

A number of ancillary buildings was completed in 1954, including store and tool sheds, fertilizer stores and a small work-shop.

The first laboratory block, containing some 30 laboratories, as well as a library and offices, was completed and occupied early in 1955 by transferring the staff from Cheshunt to their new quarters. The change-over was effected quickly and smoothly thanks to the spirit of goodwill and tolerance which prevailed. Our thanks are due to all the wives who bore the brunt of the removal with cheerfulness, and co-operated in every possible way. All the members of the scientific staff were transferred to Littlehampton with the exception of Mr. E. R. Speyer and Dr. R. Klein. Mrs. P. H. Williams also resigned her post on the office staff.

Mr. E. R. Speyer joined the staff at Cheshunt as Entomologist in 1921. Since that time he has been responsible for all the Entomological investigations of the Research Station. It must not be forgotten that in 1921 the number of insecticides available to the Industry was very limited, so Speyer had very little to help him in his work. His predecessor, Dr. L. Lloyd, had done much to control the Tomato Moth Caterpillar and the White Fly by adapting known methods to the special conditions within glasshouses, but the Red Spider Mite and countless other pests were still causing very great damage to crops in the glasshouse industry.

During the 35 years of Speyer's career at Cheshunt, he investigated all the major pests, and most of the minor ones, to such good purpose that his name became known all over the world as one who had laid the foundations of so much of our knowledge of these pests.

The Red Spider Mite which started in cucumber houses, soon became a pest dreaded by tomato growers, who were spending large sums on spraying with unsatisfactory results. Speyer discovered that the vapours of naphthalene were toxic to this mite and devised a special techinque for the treatment of glasshouse crops. The method was in active use for some time until the new white oil emulsions were discovered and introduced to this country from America. Later Speyer discovered a very active strain of *Encarsia formosa*, the Chalcid parasite of the Greenhouse White Fly. He devised methods for breeding and distributing it in very large quantities all over the British Isles and also overseas. It was so effective that at one time it seemed likely that the White Fly would be completely eliminated. Unfortunately, when Cheshunt was closed down, the breeding and distribution of the White Fly Parasite ceased and seems to be lost to this country. The story of Speyer's successes is to be found in the Reports of the Cheshunt Station, and in scientific literature. He retired on reaching the age limit, and we were all very sorry to lose such a brilliant and genial colleague. We wish him good health and much happiness in his retirement, with a sufficient number of scientific tasks to maintain his interest in his life's work. The glasshouse industry in this country owes him a very considerable debt of gratitude for the skill and devotion which he applied to his investigations.

Dr. R. Klein had only been with us at Cheshunt for two years on a temporary appointment, lasting until we were transferred to Sussex. Dr. Klein had started the investigation of the soil bacteria

involved in the nitrogen cycle with special reference to steam sterilization and had made considerable headway when his appointment came to an end. We were sorry he could not continue these most important investigations, but are glad that he has found an interesting appointment in the mushroom industry.

Mrs. P. H. Williams joined the office staff in 1931 as Miss Joyce Masson and continued thereon after her marriage. She was well known to all the growers who used to visit us at Cheshunt so regularly, as a most efficient and helpful member of the staff. We were very sorry when she decided to leave us.

The erection of dwelling accommodation for the staff was commenced in a very small way by building a detached house for occupation by the nursery manager and a pair of cottages for other members of the staff in the south-western corner of the site. Other cottages will be erected later, as funds are made available.

(b) Outside land.

Part of the site lies to the north of the railway line joining Angmering and Littlehampton. The north-westerly field of 7½ acres has been down to grass for a considerable time. It has been set aside as a source of top spit soil for all future work of the Institute. In this way the soil used each year for propagation and for all pot work will be approximately the same for all time. The soil in this field is excellent in every way, and being some six-feet deep, it will, with suitable attention, serve its purpose admirably. A level crossing has to be negotiated to reach the north side of the railway line, but arrangements for doing so have been made with British Railways and strict orders governing its use with safety are in force.

A public footpath which passed from south-west to north-east across the site has been diverted after full compliance with all the necessary legal procedure. It now passes along Norway Lane, a delightful little road-way which runs along the western boundary. The last portion of the right-of-way still crosses the most north-easterly field, where it will not interfere with the work.

More than half our area will not be used immediately for research purposes and it has been decided to meet the requests of the local committee of the National Farmers' Union to devote it to the cultivation of food crops. An ordinary arable rotation is not advisable owing to the danger of introducing virus and other diseases into our glasshouses. It has been decided, therefore, to adopt the simple three year plan for a first year of wheat, followed by oats under-sown with red clover in the second year, and then in the third year to take a crop of clover hay followed when possible by a second crop of clover for seed.

(c) Scope of the Institute.

The function of the Cheshunt Research Station was to investigate **all** problems that a grower of commercial crops in glasshouses was likely to encounter. Owing to the restricted area of glass at Cheshunt it was possible to study only a few of the most important crops. At Littlehampton the scope must be extended to cover a much wider field, although at present it has been possible to grow only tomatoes, cucumbers, carnations, chrysanthemums and lettuce. Mushrooms also have been grown on a small scale in the shed brought down from Cheshunt. It is hoped to include roses and pot plants at an early date.

The work of the Institute also includes the investigation of flowering plants and shrubs in the open. This will be undertaken in the land to the south and west of the glasshouses. As a preliminary to this work, the land has been levelled and sown down to grass. Plots for flower investigation will be cut out of this land as the need arises. The presence of turf around the plots will provide for clean and pleasant working, and will maintain the land in good condition.

Following the closing down of the Mushroom Research Association at Yaxley in October, 1954, the Government decided that the work should be continued at Littlehampton, and that those members of the Yaxley staff who wished to do so would be transferred to the Institute. In consequence, we welcomed the arrival of the chemist, Mr. Flegg, his assistant Miss Warman, and also the mycologist, Miss Gandy.

By this means the research programme of the Mushroom Growers' Research Association is being developed at Littlehampton without much disturbance.

Obituary

A. A. RICHARDS, M.B.E.

Nursery Manager and Demonstrator: Experimental and Research Station, Cheshunt

Mr. A. A. Richards spent his young life in Devon and Berkshire and from his childhood he was surrounded by influences of the country. It was not surprising, therefore, that he gradually slipped into the world of horticulture, which he graced up to the moment of his death.

Most of his early training took place at the John Innes Horticultural Research Station when it was at Merton; also with the firm of Suttons at Reading.

Mr. Richards was appointed foreman in charge of the glasshouses of the Cheshunt Research Station at its inception in 1913. During the 1914-1918 war he served with the Royal Veterinary Corps where he was fortunate to work under some excellent specialists and learned a good deal about diseases and pests of horses, which stood him in good stead when he returned to Cheshunt. At the end of the Second World War he was made Nursery Manager and Demonstrator, in which capacity he served until his retirement in the Autumn of 1954.

The name of A. A. Richards is familiar to all glasshouse nurserymen in the British Isles and also in many parts of the world, for he met most of the thousands of visitors that have honoured the Research Station with a visit. His quiet, genial manner made him popular wherever he went and in recent years he was much sought after as lecturer and judge. He was the author of two books on the cultivation of tomatoes and mushrooms respectively. He was a brilliant cultivator of plants, and a painstaking experimentor. He was created a Member of the Most Excellent Order of the British Empire by Her Majesty the Queen in the first year of her reign, for his services to horticulture.

One could always be sure of finding him at the Research Station at hours when everyone else had gone home to rest. It was his life and his love.

When he retired he took a small nursery at Benington, near Stevenage, in Hertfordshire, and had hardly settled down in it before he lost his eldest grand-daughter. To a man who had lived for his family, this must have been a serious shock; a month later he died on his nursery as the result of heart failure.

Mr. Richards' war-time experiences attracted him to the British Legion. He was an active supporter of the Cheshunt, Waltham Cross and Turnford Branch since the beginning. During his time he served in many official capacities including the Chairmanship of the British Legion Club. As a skilled horticulturist and a friend of the grower he will be greatly missed, but those who knew him best will mourn the passing of a gentle, kindly, tolerant man full of reminiscences of the past—told with an impish twinkle in the eye.

He leaves a widow and one married daughter to whom we offer our most sincere sympathy.

W.F.B.

2. Investigations in the Glasshouses

1. EXPERIMENTS IN 1954

The construction of the first group of glasshouses was not completed until 1954, but as each block was finished the task of preparing for a first crop of tomatoes began.

Surplus soil which had been lying in heaps along the inside of the wall and adjacent to purlin posts was taken away. The ground was dug as deeply as possible but it was very hard, and as the temporary water supply was insufficient to soften it, digging was limited to about nine inches.

Every attempt was made to wet the subsoil, however, by soaking it with water. Having regard to the soil analysis figures, lime was not applied to any of the houses, and in blocks B and C destined to be used for calibration experiments all fertilizers were withheld. On the instruction of the Governing Body stable manure only at the rate of 20 tons per acre was dug into the top spit.

Then blocks A, D and E were given the usual tomato treatment, namely:

Horse manure ...	30 tons per acre	Bone Meal ...	½ ton per acre
Hoof and horn ...	½ ton per acre	Sulphate of potash ...	½ ton per acre

Tomatoes were planted in all blocks as they became available. Planting dates and varieties were as follows:—

Block A	– 21.5.54	–	Potentate	Block D	– 30.4.54	–	Potentate
Block B	– 4.5.54	–	E.S.5	Block E	– 12.5.54	–	Potentate
Block C	– 26.4.54	–	E.S.5	Block F	– 10.6.54	–	Hybrids

The results of growing tomatoes in the cucumber block A are given in Tables I and II. In each house there were eight large plots, four on each side and two small plots, one on each side at the south end. The variety was Potentate and although there was some variation in different parts of each house the yields were high for they varied from 73.63 tons per acre in house 6 to 79.25 tons per acre in house 3.

Blocks B and C were set apart for calibration trials. They were unmanured except for the light dressing of horse manure dug in before planting. Each house was divided up into 56 plots, 28 on each side of a central path. With the exception of the extreme end plots, each plot contained 10 plants. The variety in each block was E.S.5.

The variation from plot to plot is considerable. The plot yields are recorded in Tables III and IV. The yield per acre also varied from house to house as follows:—

Block B

House 1	46.12 tons per acre
,, 2	40.44 ,, ,, ,,
,, 3	40.04 ,, ,, ,,
,, 4	42.25 ,, ,, ,,

Block C

House 1	41.40 tons per acre
,, 2	35.71 ,, ,, ,,
,, 3	43.11 ,, ,, ,,
,, 4	41.77 ,, ,, ,,

Block D

The crop yield from the variety E.S.5 varied from house to house as follows:—

No. 1	62.79 tons per acre
,, 2	65.89 ,, ,, ,,
,, 3	66.25 ,, ,, ,,
,, 4	64.75 ,, ,, ,,

Each house was divided into 56 plots, there being 28 plots on either side of a central path. There was considerable variation in this case also. The results are given in Table V.

In block E—the carnation block—the yield from Potentate varied from 54.99 tons per acre in house 3 to 61.94 tons pere acre in house 1. Here also there was a good deal of variation in different parts of the houses. The results are given in Table VI.

TABLE I

BLOCK A

VARIETY—POTENTATE *Horse manure and complete fertiliser added*
Sown 29th March, 1954 *Potted 15th April* *Planted 21st–22nd May*

HOUSE 1 74.51 tons/acre						HOUSE 2 74.29 tons/acre					
Plot No.	Average Per Plant	Total No. Plants	Plot No.	Average Per Plant	Total No. Plants	Plot No.	Average Per Plant	Total No. Plants	Plot No.	Average Per Plant	Total No. Plants
5	lbs. 14.281	4	6	lbs. 16.578	4	5	lbs. 17.437	4	6	lbs. 15.743	4
4	10.280	48	7	10.637	48	4	10.484	48	7	10.019	48
3	10.099	52	8	10.597	52	3	10.418	52	8	9.745	52
2	10.405	52	9	10.256	52	2	10.957	52	9	10.073	52
1	9.878	52	10	10.568	52	1	10.534	52	10	10.030	52

Total yield per house— 4341 lb. 4 oz.

Total yield per house— 4328 lbs 10½ oz.

HOUSE 3 79.25 tons/acre						HOUSE 4 75.55 tons/acre					
Plot No.	Average Per Plant	Total No. Plants	Plot No.	Average Per Plant	Total No. Plants	Plot No.	Average Per Plant	Total No. Plants	Plot No.	Average Per Plant	Total No. Plants
5	lbs. 13.758	4	6	lbs. 20.083	4	5	lbs. 16.745	4	6	lbs. 17.453	4
4	11.050	48	7	11.761	48	4	10.736	48	7	11.415	48
3	10.701	52	8	11.430	52	3	10.167	52	8	10.764	52
2	10.692	52	9	10.615	52	2	10.784	52	9	10.237	52
1	11.175	52	10	10.495	52	1	9.878	52	10	9.587	52

Total yield per house— 4617 lb. 11 oz.

Total yield per house— 4401 lb. 10½ oz.

TABLE II

BLOCK A

VARIETY—POTENTATE *Horse manure and complete fertiliser added*

Sown 29th March, 1954 *Potted 15th April* *Planted 21st–22nd May*

HOUSE 5 75.04 tons/acre						HOUSE 6 73.63 tons/acre					
Plot No.	Average Per Plant	Total No. Plants	Plot No.	Average Per Plant	Total No. Plants	Plot No.	Average Per Plant	Total No. Plants	Plot No.	Average Per Plant	Total No. Plants
	lb.			lb.			lb.			lb.	
5	16.187	4	6	15.656	4	5	15.000	4	6	18.000	4
4	10.876	48	7	10.764	48	4	10.626	48	7	10.714	48
3	10.532	52	8	10.730	52	3	10.025	52	8	10.880	52
2	10.441	52	9	10.028	52	2	10.110	52	9	9.974	52
1	9.966	52	10	9.954	52	1	10.052	52	10	9.912	52

Total yield per house—
4371 lb. 14½ oz.

Total yield per house—
4289 lb. 15½ oz.

HOUSE 7 73.88 tons/acre					
Plot No.	Average Per Plant	Total No. Plants	Plot No.	Average Per Plant	Total No. Plants
	lb.			lb.	
5	15.187	4	6	11.437	4
4	10.929	48	7	10.945	48
3	9.973	52	8	10.216	52
2	10.290	52	9	9.622	52
1	10.318	52	10	9.318	52

Total yield per house—
4262 lb. 14 oz.

TABLE III

BLOCK B

VARIETY—E.S.5 *Horse manure added: no fertiliser*

Sown 15th March, 1954 *Potted 10th April* *Planted 4th May*

HOUSE 1 46.12 tons/acre						HOUSE 2 40.44 tons/acre					
Plot No.	Average Per Plant	Total No. Plants	Plot No.	Average Per Plant	Total No. Plants	Plot No.	Average Per Plant	Total No. Plants	Plot No.	Average Per Plant	Total No. Plants
28	lb. 10.862	5	29	lb. 9.537	5	28	lbs. 9.775	5	29	lb. 8.050	5
27	9.512	10	30	6.056	10	27	6.143	10	30	4.018	10
26	8.775	10	31	6.425	10	26	5.850	10	31	3.750	10
25	8.012	10	32	5.681	10	25	6.875	10	32	4.681	10
24	6.487	10	33	5.731	10	24	5.487	10	33	5.937	10
23	8.375	10	34	5.787	10	23	5.400	10	34	7.181	10
22	7.362	10	35	4.893	10	22	4.818	10	35	6.537	10
21	8.175	10	36	5.975	10	21	6.556	10	36	6.081	10
20	7.068	10	37	5.685	10	20	7.426	10	37	5.750	10
19	8.087	10	38	5.831	10	19	6.300	10	38	5.743	10
18	8.387	10	39	5.525	10	18	6.575	10	39	5.550	10
17	7.618	10	40	5.693	10	17	5.380	10	40	5.768	10
16	5.887	10	41	6.368	10	16	4.987	10	41	6.625	10
15	6.425	10	42	5.150	10	15	5.175	10	42	7.968	10
14	7.737	10	43	5.775	10	14	6.493	10	43	7.437	10
13	7.331	10	44	5.225	10	13	5.162	10	44	5.843	10
12	5.568	10	45	5.081	10	12	5.606	10	45	6.681	10
11	4.593	10	46	4.856	10	11	4.712	10	46	6.768	10
10	6.412	10	47	4.981	10	10	4.693	10	47	5.000	10
9	4.918	10	48	4.956	10	9	4.900	10	48	4.568	10
8	6.562	10	49	3.681	10	8	4.668	10	49	4.593	10
7	7.550	10	50	4.718	10	7	3.956	10	50	5.018	10
6	6.581	10	51	4.431	10	6	5.237	10	51	5.262	10
5	8.406	10	52	4.325	10	5	5.350	10	52	5.450	10
4	7.356	10	53	4.693	10	4	5.593	10	53	5.825	10
3	7.306	10	54	5.600	10	3	4.418	10	54	4.768	10
2	7.775	10	55	5.968	10	2	4.043	10	55	4.887	10
1	9.683	15	56	7.141	15	1	6.313	15	56	6.345	15

Total yield per house—
3617 lb. 6 oz.

Total yield per house—
3172 lb. 3 oz.

TABLE III—*continued*

BLOCK B

VARIETY—E.S.5 *Horse manure added: no fertiliser*

Sown 15th March, 1954 *Potted 10th April* *Planted 4th May*

HOUSE 3 40.04 tons/acre						HOUSE 4 42.25 tons/acre					
Plot Po.	Average Per Plant	Total No. Plants	Plot No.	Average Per Plant	Total No. Plants	Plot No.	Average Per Plant	Total No. Plants	Plot No.	Average Per Plant	Total No. Plants
	lb.			lb.			lb.			lb.	
28	8.987	5	29	8.720	5	28	12.025	5	29	12.387	5
27	4.668	10	30	5.856	10	27	6.868	10	30	7.712	10
26	4.275	10	31	5.200	10	26	7.162	10	31	6.656	10
25	6.062	10	32	5.962	10	25	6.462	10	32	6.743	10
24	6.487	10	33	6.050	10	24	6.168	10	33	6.512	10
23	5.956	10	34	5.237	10	23	5.450	10	34	6.268	10
22	5.418	10	35	4.731	10	22	5.693	10	35	5.587	10
21	4.781	10	36	6.243	10	21	4.600	10	36	6.193	10
20	5.768	10	37	6.688	10	20	4.975	10	37	6.131	10
19	6.475	10	38	6.600	10	19	6.512	10	38	6.706	10
18	5.531	10	39	6.381	10	18	7.693	10	39	7.068	10
17	6.593	10	40	6.556	10	17	7.250	10	40	6.493	10
16	6.818	10	41	6.318	10	16	5.362	10	41	4.906	10
15	5.575	10	42	5.925	10	15	6.012	10	42	6.768	10
14	6.081	10	43	5.168	10	14	6.975	10	43	7.387	10
13	5.425	10	44	5.075	10	13	5.056	10	44	6.325	10
12	6.125	10	45	5.162	10	12	4.525	10	45	6.662	10
11	5.281	10	46	4.587	10	11	4.206	10	46	5.787	10
10	6.662	10	47	4.756	10	10	3.750	10	47	4.831	10
9	5.831	10	48	4.937	10	9	4.793	10	48	4.681	10
8	4.212	10	49	4.100	10	8	6.100	10	49	5.668	10
7	5.168	10	50	3.475	10	7	6.050	10	50	6.025	10
6	5.175	10	51	3.637	10	6	5.943	10	51	5.900	10
5	5.231	10	52	3.862	10	5	4.875	10	52	5.731	10
4	6.643	10	53	4.500	10	4	3.750	10	53	6.687	10
3	5.862	10	54	4.600	10	3	6.025	10	54	6.237	10
2	5.843	10	55	4.606	10	2	4.925	10	55	6.781	10
1	6.687	15	56	7.341	15	1	6.179	15	56	6.875	15

Total yield per house—
3140 lb. 10 oz.

Total yield per house—
3313 lb. 9½ oz.

TABLE IV

BLOCK C

VARIETY—E.S.5 *Horse manure applied: no fertiliser*

Sown 15th March, 1954 *Potted 10th April* *Planted 26th April*

HOUSE 1 41.40 tons/acre						HOUSE 2 35.71 tons/acre					
Plot No.	Average Per Plant	Total No. Plants	Plot No.	Average Per Plant	Total No. Plants	Plot No.	Average Per Plant	Total No. Plants	Plot No.	Average Per Plant	Total No. Plants
	lb.			lb.			lb.			lb.	
28	7.325	5	29	7.112	5	28	7.675	5	29	7.562	5
27	6.975	10	30	5.118	10	27	4.443	10	30	5.350	10
26	7.181	10	31	5.018	10	26	5.350	10	31	4.275	10
25	6.868	10	32	5.268	10	25	4.287	10	32	4.918	10
24	6.475	10	33	4.425	10	24	5.000	10	33	4.306	10
23	5.906	10	34	4.525	10	23	4.512	10	34	4.193	10
22	5.850	10	35	4.012	10	22	4.225	10	35	4.106	10
21	5.881	10	36	4.218	10	21	3.843	10	36	4.950	10
20	5.681	10	37	4.781	10	20	3.700	10	37	3.443	10
19	6.487	10	38	4.381	10	19	3.906	10	38	3.725	10
18	6.625	10	39	3.243	10	18	4.656	10	39	3.712	10
17	6.212	10	40	3.431	10	17	4.493	10	40	3.987	10
16	5.625	10	41	3.843	10	16	3.850	10	41	4.093	10
15	7.281	10	42	4.162	10	15	4.218	10	42	4.393	10
14	7.350	10	43	5.887	10	14	5.337	10	43	5.137	10
13	6.362	10	44	3.650	10	13	4.300	10	44	4.468	10
12	6.512	10	45	4.556	10	12	4.906	10	45	4.350	10
11	7.050	10	46	4.356	10	11	5.512	10	46	4.675	10
10	7.643	10	47	4.706	10	10	4.262	10	47	4.675	10
9	8.231	10	48	4.387	10	9	4.287	10	48	4.950	10
8	6.700	10	49	4.287	10	8	5.468	10	49	4.852	10
7	6. 987	10	50	4.593	10	7	5.456	10	50	3.962	10
6	7.268	10	51	5.050	10	6	5.775	10	51	5.012	10
5	7.393	10	52	4.868	10	5	5.356	10	52	4.287	10
4	6.425	10	53	5.425	10	4	7.937	10	53	6.518	10
3	6.743	10	54	5.368	10	3	6.318	10	54	7.031	10
2	6.337	10	55	6.643	10	2	7.006	10	55	6.981	10
1	7.679	15	56	7.845	15	1	7.704	15	56	7.478	15

Total yield per house—
3247 lb 2½ oz.

Total yield per house—
2801 lb. 0½ oz.

TABLE IV—*continued*

BLOCK C

VARIETY—E.S.5 *Horse manure applied: no fertiliser*

Sown 15th March, 1954 *Potted 10th April* *Planted 26th April*

HOUSE 3 43.11 tons/acre						HOUSE 4 41.77 tons/acre					
Plot No.	Average Per Plant	Total No. Plants	Plot No.	Average Per Plant	Total No. Plants	Plot No.	Average Per Plant	Total No. Plants	Plot No.	Average Per Plant	Total No. Plants
	lb.			lb.			lb.			lb.	
28	7.512	5	29	5.650	5	28	6.125	5	29	9.212	5
27	5.175	10	30	5.275	10	27	5.587	10	30	6.581	10
26	5.906	10	31	6.575	10	26	5.343	10	31	7.100	10
25	5.306	10	32	5.856	10	25	5.406	10	32	7.818	10
24	4.768	10	33	5.550	10	24	6.743	10	33	6.512	10
23	3.956	10	34	5.206	10	23	5.906	10	34	6.318	10
22	4.112	10	35	5.575	10	22	5.300	10	35	5.893	10
21	4.481	10	36	5.575	10	21	5.143	10	36	5.618	10
20	4.968	10	37	5.000	10	20	5.443	10	37	5.175	10
19	4.418	10	38	6.318	10	19	4.630	10	38	5.793	10
18	6.650	10	39	6.718	10	18	4.931	10	39	5.862	10
17	5.300	10	40	6.825	10	17	4.912	10	40	4.781	10
16	5.612	10	41	7.800	10	16	6.243	10	41	5.100	10
15	5.731	10	42	7.768	10	15	5.518	10	42	5.956	10
14	5.950	10	43	7.262	10	14	7.137	10	43	6.352	10
13	6.762	10	44	5.968	10	13	5.112	10	44	5.131	10
12	6.718	10	45	5.662	10	12	6.125	10	45	4.587	10
11	6.037	10	46	5.743	10	11	4.431	10	46	4.662	10
10	5.343	10	47	5.218	10	10	5.350	10	47	4.587	10
9	5.518	10	48	5.062	10	9	5.975	10	48	4.531	10
8	5.825	10	49	5.631	10	8	5.162	10	49	5.425	10
7	6.406	10	50	5.412	10	7	6.187	10	50	4.512	10
6	7.412	10	51	4.637	10	6	5.375	10	51	5.325	10
5	5.937	10	52	5.118	10	5	5.468	10	52	5.287	10
4	8.268	10	53	6.243	10	4	6.287	10	53	6.256	10
3	7.181	10	54	6.806	10	3	6.287	10	54	5.968	10
2	7.437	10	55	8.575	10	2	7.306	10	55	8.275	10
1	8.054	15	56	8.037	15	1	7.375	15	56	8.204	15

Total yield per house—
3381 lb. 0½ oz.

Total yield per house—
3276 lb.

TABLE V

BLOCK D

VARIETY—E.S.5 *Horse manure and complete fertiliser added*

Sown 15th March, 1954 *Potted 10th April* *Planted 30th April*

HOUSE 1 62.79 tons/acre						HOUSE 2 65.89 tons/acre					
Plot No.	Average Per Plant	Total No. Plants	Plot No.	Average Per Plant	Total No. Plants	Plot No.	Average Per Plant	Total No. Plants	Plot No.	Average Per Plant	Total No. Plants
	lb.			lb.			lb.			lb.	
28	11.268	10	29	14.468	10	28	14.200	10	29	14.962	10
27	9.681	20	30	9.365	20	27	9.906	20	30	9.178	20
26	8.456	20	31	9.306	20	26	9.121	20	31	8.896	20
25	8.140	20	32	8.190	20	25	8.153	20	32	8.515	20
24	8.118	20	33	8.843	20	24	8.428	20	33	8.093	20
23	8.456	20	34	7.950	20	23	8.831	20	34	8.278	20
22	7.506	20	35	8.175	20	22	8.021	20	35	8.471	20
21	8.093	20	36	7.943	20	21	8.743	20	36	8.212	20
20	7.996	20	37	7.978	20	20	8.415	20	37	8.290	20
19	7.778	20	38	8.087	20	19	8.728	20	38	8.987	20
18	7.815	20	39	8.168	20	18	8.334	20	39	8.246	20
17	7.834	20	40	7.875	20	17	9.062	20	40	9.025	20
16	7.768	20	41	8.528	20	16	8.443	20	41	8.643	20
15	7.821	20	42	8.515	20	15	8.987	20	42	8.587	20
14	8.378	20	43	8.681	20	14	8.787	20	43	8.990	20
13	8.371	20	44	8.431	20	13	9.084	20	44	8.843	20
12	8.053	20	45	8.215	20	12	8.425	20	45	8.237	20
11	7.803	20	46	8.121	20	11	9.206	20	46	8.521	20
10	8.915	20	47	8.721	20	10	9.696	20	47	8.981	20
9	9.053	20	48	8.818	20	9	9.100	20	48	8.856	20
8	9.034	20	49	8.496	20	8	10.121	20	49	8.700	20
7	9.053	20	50	8.846	20	7	9.913	20	50	8.837	20
6	8.768	20	51	9.806	20	6	9.846	20	51	9.065	20
5	9.396	20	52	9.796	20	5	10.415	20	52	9.887	20
4	8.681	20	53	9.196	20	4	9.609	20	53	10.137	20
3	10.543	20	54	8.834	20	3	10.153	20	54	10.075	20
2	10.903	20	55	10.234	20	2	11.043	20	55	10.040	20
1	10.927	30	56	10.502	30	1	11.262	30	56	10.787	30

Total yield per house—
9849 lb. 6½ oz.

Total yield per house—
10335 lb. 15½ oz.

TABLE V—*continued*

BLOCK D

VARIETY E.S.5 *Horse manure and complete fertiliser added*

Sown 15th March, 1954 *Potted 10th April* *Planted 30th April*

HOUSE 3 66.25 tons acre						HOUSE 4 64.75 tons/acre					
Plot No.	Average Per Plant	Total No. Plants	Plot No.	Average Per Plant	Total No. Plants	Plot No.	Average Per Plant	Total No. Plants	Plot No.	Average Per Plant	Total No. Plants
	lb.			lb.			lb.			lb.	
28	13.275	10	29	14.943	10	28	14.131	10	29	13.918	10
27	9.565	20	30	9.765	20	27	9.950	20	30	9.203	20
26	9.018	20	31	9.168	20	26	8.653	20	31	8.168	20
25	8.759	20	32	9.296	20	25	8.628	20	32	8.734	20
24	8.493	20	33	8.756	20	24	9.203	20	33	8.431	20
23	8.406	20	34	7.690	20	23	8.681	20	34	9.191	20
22	8.309	20	35	7.916	20	22	8.209	20	35	8.431	20
21	8.746	20	36	8.315	20	21	8.350	20	36	8.318	20
20	8.431	20	37	8.965	20	20	9.434	20	37	8.653	20
19	8.241	20	38	8.306	20	19	9.509	20	38	8.912	20
18	8.571	20	39	8.150	20	18	8.596	20	39	8.932	20
17	8.453	20	40	8.525	20	17	8.481	20	40	8.678	20
16	9.212	20	41	8.921	20	16	8.715	20	41	8.912	20
15	9.203	20	42	8.928	20	15	8.862	20	42	9.206	20
14	8.584	20	43	8.728	20	14	8.421	20	43	9.693	20
13	9.418	20	44	8.843	20	13	9.128	20	44	9.241	20
12	9.286	20	45	9.137	20	12	8.741	20	45	9.096	20
11	9.396	20	46	9.087	20	11	9.187	20	46	9.706	20
10	9.212	20	47	9.325	20	10	10.434	20	47	9.321	20
9	9.900	20	48	9.231	20	9	9.250	20	48	9.637	20
8	9.684	20	49	10.093	20	8	9.356	20	49	9.056	20
7	9.787	20	50	9.159	20	7	9.041	20	50	9.662	20
6	10.068	20	51	9.443	20	6	9.737	20	51	9.462	20
5	9.553	20	52	9.741	20	5	9.791	20	52	10.156	20
4	9.834	20	53	9.325	20	4	9.478	20	53	9.641	20
3	9.996	20	54	10.391	20	3	10.300	20	54	10.462	20
2	10.953	20	55	10.231	20	2	9.018	20	55	9.821	20
1	10.443	30	56	10.141	30	1	10.847	30	56	10.393	30

Total yield per house—
10392 lb. 8½ oz.

Total yield per house—
10430 lb. 4 oz.

TABLE VI

BLOCK E

VARIETY—POTENTATE *Horse manure and complete fertiliser added*

Sown 29th March, 1954 *Potted 15th April* *Planted 12th May*

HOUSE 1 61.94 tons/acre						HOUSE 2 57.59 tons/acre						HOUSE 3 54.99 tons/acre					
Plot No.	Average Per Plant	Total No. Plants	Plot No.	Average Per Plant	Total No. Plants	Plot No.	Average Per Plant	Total No. Plants	Plot No.	Average Per Plant	Total No. Plants	Plot No.	Average Per Plant	Total No. Plants	Plot No.	Average Per Plant	Total No. Plants
6	lbs. 14.504	13	7	lbs. 16.058	14	6	lbs. 15.706	13	7	lbs. 14.776	14	6	lbs. 13.836	14	7	lbs. 15.234	12
5	9.235	169	8	8.593	182	5	8.380	169	8	8.085	182	5	8.264	169	8	8.572	156
4	18.650	169	9	8.199	182	4	7.543	169	9	7.599	182	4	7.523	169	9	8.533	156
3	8.947	169	10	7.728	182	3	7.722	169	10	7.495	182	3	7.711	169	10	8.523	156
2	8.883	169	11	8.208	182	2	8.276	169	11	8.164	182	2	7.552	169	11	8.591	156
1	9.560	39	12	8.568	42	1	8.057	39	12	8.860	42	1	9.147	39	12	9.423	36

Total yield per house — 13117 lb. 14½ oz.

Total yield per house— 12196 lb. 15½ oz.

Total yield per house— 11645 lb. 8½ oz.

2. EXPERIMENTS IN 1955

(a) Cucumbers

In preparation of the soil this year it was possible, after the first year's cultivation, to dig it to a depth of two spits and to flood it with water at the rate of 160,000 gallons per acre.

After the land had dried sufficiently, powdered hydrated lime was applied uniformly using 1lb. per square foot. This was forked into the top spit and then watered in.

Standard cucumber beds were then laid down, mixing two parts turfy loam and one part strawy horse manure together. The original beds were 15 inches wide and about 10 inches high.

In view of the fact that this crop of cucumbers was the first to be grown, it was decided to make it a trial of varieties, using the following:—

Butcher's Disease Resister
Challenger
Clapham's Market
Harrison's Favourite
Harrison's Telegraph Improved
Harrison's Torpedo
Sutton's Everyday
Sutton's Satisfaction
Rochford's Market

Six plots were arranged in each house, and the varieties were randomised. The crop results are given in Table VII, the average yields varied from 93.59 to 111.28 tons per acre. For a late planted crop this is a reasonable return, 120 tons per acre, or in the older nomenclature two flats per plot, being recognised in the industry as being a satisfactory but not exciting yield.

During the course of the year a number of crosses were made. The seed produced (F1) will be used in 1956. Our thanks are due to Miss Gurney who kindly undertook this work.

(b) Tomatoes

As in the case of the cucumbers it was possible to dig the soil properly to a depth of 20 inches because the previous crop had loosened it up sufficiently. After thorough digging it was well flooded with water in an attempt to wet the subsoil.

(i) Calibration experiments

Blocks B and C were treated as for 1954. All fertilizers were withheld, but horse manure at the rate of 20 tons per acre was applied. Again the variety used was E.S.5.

The results are given plot by plot in Tables VIII and IX.

During 1954 and 1955 there have been considerable variations in the yield from the plots and in the appearance of the plants.

In 1954 a row of plants around the insides of the walls, and also groups of plants near purlins and gutter posts showed remarkably good strong growth, while the remainder were rather thin. On plotting the position of the strong plants it was clear that they were planted where soil had been thrown out of the "footings" and had laid in small heaps for some time. This had kept the soil beneath in a moist condition whereas the rest of the surrounding soil had gradually become drier and drier. When the heaps of soil were cleared away, and the ground was dug and flooded, the damp places which had been covered with soil absorbed water better than the drier soil. The stronger growth in 1954,

TABLE VII

Cucumber Trials—1955 *Crop yield in lbs. per plant*

House	Plot	Variety	May	June	July	Aug.	Sept.	Oct.	Nov.	Total	Tons/Acre	
A.1	1	Clapham's Market	13.67	20.09	15.65	7.48	8.44	4.42	1.47	71.22	106.83	102.36
A.2	6	,, ,,	11.83	18.85	15.53	8.69	7.49	5.18	1.35	68.88	103.34	
A.4	6	,, ,,	8.57	18.26	14.96	10.36	6.75	4.13	1.57	64.60	96.90	
A.1	2	Sutton's Everyday	14.72	22.45	14.54	8.49	8.12	4.41	2.12	74.87	112.30	108.23
A.2	4	,, ,,	14.08	20.35	12.06	9.39	7.42	5.14	2.25	70.73	106.09	
A.4	2	,, ,,	11.89	20.16	12.63	9.81	8.29	5.20	2.88	70.86	106.29	
A.1	3	Sutton's Satisfaction	11.83	21.78	15.85	7.06	6.94	3.55	1.32	68.34	102.51	93.59
A.2	5	,, ,,	9.36	17.74	12.52	8.46	7.49	2.84	1.93	60.36	90.54	
A.4	5	,, ,,	7.28	19.38	10.62	10.56	6.38	2.78	1.47	58.48	87.72	
A.1	4	Harrison's Torpedo	14.02	22.07	12.46	6.95	6.34	4.21	1.49	67.56	101.34	101.73
A.3	2	,, ,,	10.51	21.03	11.17	10.71	8.86	4.09	1.61	68.08	102.12	
A.4	4	,, ,,	10.38	20.74	11.44	—replanted		No. xx x——		42.56	63.84	
A.1	5	Harrison's Teleg. Imprvd.	18.93	22.67	12.41	6.87	6.93	4.64	2.10	73.32	109.98	107.88
A.3	1	,, ,, ,,	15.08	21.15	11.32	10.77	8.41	3.84	1.60	72.88	109.32	
A.4	3	,, ,, ,,	14.62	21.14	12.68	9.46	6.40	3.39	1.87	69.56	104.34	
A.1	6	Rochford's Market	14.25	21.03	15.60	8.29	8.00	4.54	2.31	74.04	111.06	111.28
A.3	3	,, ,,	12.91	21.34	13.54	10.74	9.81	4.58	1.62	74.56	111.84	
A.4	1	,, ,,	18.04	22.32	16.70	11.42	6.74	4.35	1.60	73.96	110.94	
A.2	2	Harrison's Favourite	13.39	19.37	11.67	8.72	7.81	4.85	2.23	68.07	102.10	105.00
A.3	6	,, ,,	13.19	21.30	12.09	10.62	7.29	4.82	1.99	71.33	106.99	
A.5	3	,, ,,	10.25	23.63	15.79	8.50	6.25	3.22	2.43	70.00	105.00	
A.2	3	Challenger	12.62	22.61	12.14	10.57	8.48	4.79	1.23	72.48	108.72	107.89
A.3	5	,,	11.68	23.46	14.26	10.76	7.63	5.16	1.15	74.13	111.19	
A.5	1	,,	9.12	21.69	15.67	9.05	7.17	2.81	3.58	69.10	103.65	
A.2	1	Butcher's Disease Resister	11.51	19.35	15.44	10.68	7.37	5.51	1.68	71.55	107.32	105.60
A.3	4	,, ,, ,,	12.46	20.10	13.86	10.33	9.50	5.14	1.92	73.32	109.98	
A.5	2	,, ,, ,,	10.61	21.42	17.51	10.70	7.67	4.76	2.01	74.69	112.04	
A.5	4	,, ,, ,,	8.53	23.00	17.83	11.93	8.09	4.55	1.62	75.59	113.38	
A.5	5	,, ,, ,,	8.78	22.66	18.19	10.19	7.84	4.45	1.89	74.00	111.00	
A.5	6	,, ,, ,,	7.29	21.72	17.16	9.78	6.79	4.56	2.19	68.90	103.35	
A.6	1	,, ,, ,,	7.44	22.58	16.10	11.93	6.54	3.89	2.14	70.64	105.96	
A.6	2	,, ,, ,,	7.87	21.99	16.33	12.24	8.45	3.90	2.40	73.19	109.78	
A.6	3	,, ,, ,,	8.09	21.86	16.16	12.02	7.51	2.84	—	68.49	102.73	
A.6	4	,, ,, ,,	8.27	20.85	16.27	11.84	6.06	2.73	—	66.03	99.04	
A.6	5	,, ,, ,,	8.79	19.79	15.67	11.92	6.10	3.73	0.89	66.27	99.40	
A.6	6	,, ,, ,,	7.60	17.84	15.45	11.03	5.13	4.92	1.50	63.50	95.25	
A.4	4	Replant of No. xxx	—	—	—	—	8.36	4.22	3.48	16.06	24.09	

therefore, was due to the fact that the soil in these places was much wetter than in the others. In 1955 the picture changed. No longer were the plants around the walls stronger than the remainder. It was, however, noticeable that the rows on either side of the centre path in every house and in both blocks were vigorous and carried a heavy crop of good fruit. It was further noticed that the vigour of growth fell away towards the gutters. The problem was taken up by the Chemistry Department, it being shown that plants adjoining the paths had a higher nitrogen content in the leaves; it was also found that the concentration of inorganic nitrogen under the path was many times higher than in the borders.

(*ii*) *Spacing experiment*

The spacing experiments started at Cheshunt were continued here in Block D—Houses 1 and 2—House 1 being planted with Potentate and House 2 with E.S.5.

Both houses had received the standard manurial treatment in 1954 and it was repeated this year. The spacing treatments, repeated four times in each house, were as follows:—

Plot A 16,000 plants per acre — normal spacing
B 8,000 „ „ „ — half spacing
C 24,000 „ „ „ — dense spacing
D 16,000 „ „ „ — but alternate plants were stopped at the fifth truss and all side shoots removed. These plants were taken out immediately the crop was picked
E As D, but a shoot from an adjacent plant was trained into the vacant space above the "stopped" plants.

Reducing the spacing to 8,000 plants per acre affected the crop very seriously, the average tons per acre being 104.46 Potentate and 78.53 E.S.5, in the normal spacing, and only 85.62 Potentate and 63.91 E.S.5 where the spacing was reduced to 8,000 plants per acre. The denser planting of 24,000 plants per acre yielded 106.23 tons per acre for Potentate and 79.82 tons per acre for E.S.5. Where half the plants were stopped at the fifth truss, the yield per acre for Potentate was 95.22, and 75.40 for E.S.5. Where, however, a shoot was tied in from an adjacent plant to take the place of that removed by stopping, then the yield was 106.23 tons per acre from Potentate and 77.82 from E.S.5. It seems clear from these results that a variety like E.S.5 which produces more foliage than Potentate can take more advantage of wide spacing.

It will be noted also that the yields produced by Potentate were surprisingly high. The full details are given in Tables X and XI.

(*iii*) *Cultural trial*

In House 4 of block D an experiment was arranged regarding the removal of side shoots. The results are given in Table XII, Potentate being the variety. The treatments were repeated six times and were as follows:—

F Control. The shoots were removed as in the ordinary way of cultivation, which is usually too late.
G All side shoots were removed before they had grown one inch.
H All shoots below the second truss were allowed to become 12 inches long before they were cut out. Later laterals were taken out before they were one inch long.
I All side shoots were removed except the one below the truss. This was left in and stopped after two leaves.

Very little difference was observed as a result of the different treatments, except that there was a distinct reduction in crop when all the side shoots below the first truss were allowed to grow 12 inches long before being removed. The importance of rubbing out all side shoots while they are very small is again emphasised.

TABLE VIII

BLOCK B

VARIETY—E.S.5 *Horse manure applied: no fertiliser*

Sown 21st December, 1954 *Potted 22nd January, 1955* *Planted 1st March, 1955*

HOUSE 1 63.92 tons/acre								HOUSE 2 58.14 tons/acre							
Plot No.	lbs. Per Plant	Tons Per Acre	No. Plants	Plot No.	lbs. Per Plant	Tons Per Acre	No. Plants	Plot No.	lbs. Per Plant	Tons Per Acre	No. Plants	Plot No.	lbs. Per Plant	Tons Per Acre	No. Plants
28	11.56	82.57	4	29	11.81	84.35	4	28	11.07	79.07	4	29	11.14	79.57	4
27	8.11	57.92	8	30	8.13	58.07	8	27	7.62	54.42	8	30	7.04	50.28	8
26	8.64	61.71	8	31	9.08	64.85	8	26	7.99	57.07	8	31	7.64	54.57	8
25	8.26	59.00	8	32	10.77	76.92	8	25	8.68	62.00	8	32	8.18	58.42	8
24	8.43	60.21	8	33	9.05	64.64	8	24	9.02	64.42	8	33	7.16	51.14	8
23	8.54	61.00	8	34	9.36	66.85	8	23	7.61	54.35	8	34	7.43	53.07	8
22	9.22	65.85	8	35	8.39	59.92	8	22	7.55	53.92	8	35	9.34	66.71	8
21	8.54	61.00	8	36	9.52	68.00	8	21	8.64	61.71	8	36	8.29	59.21	8
20	9.12	65.14	8	37	8.68	62.00	8	20	7.99	57.07	8	37	8.26	59.00	8
19	9.45	67.50	8	38	9.32	66.57	8	19	8.76	62.57	8	38	8.22	58.71	8
18	8.78	62.71	8	39	9.61	68.64	8	18	8.70	62.14	8	39	7.24	51.71	8
17	8.30	59.28	8	40	8.82	63.00	8	17	8.46	60.42	8	40	7.00	50.00	8
16	8.53	60.93	8	41	9.67	69.07	8	16	6.80	48.57	8	41	8.51	60.78	8
15	8.51	60.78	8	42	8.82	63.00	8	15	7.61	54.35	8	42	9.13	65.21	8
14	10.01	71.50	8	43	10.00	71.42	8	14	7.79	55.64	8	43	9.09	64.92	8
13	7.67	54.78	8	44	8.76	62.57	8	13	8.46	60.42	8	44	8.64	61.71	8
12	8.09	57.78	8	45	8.93	63.78	8	12	7.76	55.42	8	45	9.53	68.07	8
11	8.68	62.00	8	46	8.76	62.57	8	11	7.56	54.00	8	46	9.11	65.07	8
10	6.94	49.57	8	47	8.50	60.71	8	10	6.88	49.14	8	47	8.57	61.21	8
9	8.06	57.57	8	48	8.18	58.42	8	9	7.71	57.07	8	48	8.50	60.71	8
8	8.40	60.00	8	49	9.28	66.28	8	8	8.06	57.57	8	49	8.27	59.07	8
7	9.64	68.85	8	50	9.34	66.71	8	7	8.50	60.71	8	50	9.06	64.71	8
6	9.18	65.57	8	51	8.61	61.50	8	6	7.93	56.64	8	51	8.10	57.85	8
5	8.11	57.92	8	52	8.58	61.28	8	5	8.08	57.71	8	52	8.12	58.00	8
4	8.20	58.57	8	53	8.86	63.28	8	4	8.06	57.57	8	53	7.07	50.50	8
3	8.72	62.28	8	54	8.94	63.85	8	3	8.04	57.42	8	54	8.07	57.64	8
2	10.32	73.71	8	55	8.43	60.21	8	2	7.43	53.07	8	55	6.91	49.35	8
1	10.69	76.35	12	56	9.07	64.78	12	1	7.57	54.07	12	56	8.64	61.71	12

Total yield per house—
4005 lb. 9 oz.

Total yield per house—
3646 lb. 12 oz.

TABLE VIII—*continued*

BLOCK B

VARIETY E.S.5 *Horse manure applied: no fertiliser*

Sown 21st December, 1954 *Potted 22nd January, 1955* *Planted 1st March, 1955*

HOUSE 3 59.32 tons/acre								HOUSE 4 61.06 tons/acre							
Plot No.	lbs. Per Plant	Tons Per Acre	No. Plants	Plot No.	lbs. Per Plant	Tons Per Acre	No. Plants	Plot No.	lbs. Per Plant	Tons Per Acre	No. Plants	Plot No.	lbs. Per Plant	Tons Per Acre	No. Plants
28	8.67	61.92	4	29	9.73	69.50	4	28	11.42	81.57	4	29	11.25	80.35	4
27	8.23	58.78	8	30	7.15	51.07	8	27	7.94	56.71	8	30	8.84	63.14	8
26	7.36	52.57	8	31	8.86	63.28	8	26	8.85	63.21	8	31	8.32	59.42	8
25	7.76	55.42	8	32	9.43	67.35	8	25	8.86	63.28	8	32	7.89	56.35	8
24	8.66	61.85	8	33	7.50	53.57	8	24	9.56	68.28	8	33	7.07	50.50	8
23	8.43	60.21	8	34	8.21	58.64	8	23	9.17	65.50	8	34	8.38	59.85	8
22	8.21	58.64	8	35	8.14	58.14	8	22	9.46	67.57	8	35	7.57	54.07	8
21	9.33	66.64	8	36	7.72	55.14	8	21	8.87	63.35	8	36	8.13	58.07	8
20	8.74	62.42	8	37	8.08	57.71	8	20	9.69	69.21	8	37	8.03	57.35	8
19	7.08	50.57	8	38	8.27	59.07	8	19	11.02	78.71	8	38	7.89	56.35	8
18	7.45	53.21	8	39	8.82	63.00	8	18	9.44	67.42	8	39	7.32	52.28	8
17	8.53	60.92	8	40	8.90	63.57	8	17	9.47	67.64	8	40	8.13	58.07	8
16	7.52	53.71	8	41	7.36	52 57	8	16	8.67	61.92	8	41	8.91	63.64	8
15	8.48	60.56	8	42	8.21	58.64	8	15	8.51	60.78	8	42	7.74	55.28	8
14	9.40	67.14	8	43	8.05	57.50	8	14	8.31	59.35	8	43	8.89	63.50	8
13	9.56	68.28	8	44	7.76	55.42	8	13	7.79	55.64	8	44	8.00	57.14	8
12	8.63	61.64	8	45	8.32	59.42	8	12	9.18	65.57	8	45	7.81	55.78	8
11	8.82	63.00	8	46	7.23	51.64	8	11	7.53	53.78	8	46	8.93	63.78	8
10	8.66	61.85	8	47	8.39	59.92	8	10	9.44	67.42	8	47	9.30	66.42	8
9	8.19	58.50	8	48	8.00	57.14	8	9	9.21	65.78	8	48	8.57	61.21	8
8	9.63	68.78	8	49	9.45	67.50	8	8	9.28	66.28	8	49	8.66	61.85	8
7	9.19	65.64	8	50	8.26	59.00	8	7	9.16	65.42	8	50	7.87	56.21	8
6	7.14	51.00	8	51	8.94	63.85	8	6	8.09	57.78	8	51	8.22	58.71	8
5	7.28	52.00	8	52	8.78	62.71	8	5	6.94	49.57	8	52	7.84	56.00	8
4	7.98	57.00	8	53	8.65	61.78	8	4	8.71	62.21	8	53	7.16	51.14	8
3	7.34	52.42	8	54	9.05	64.64	8	3	10.32	73.71	8	54	6.69	47.78	8
2	7.88	56.28	8	55	8.64	61.71	8	2	10.30	73.57	8	55	7.24	51.71	8
1	7.82	55.86	12	56	8.17	58.35	12	1	9.00	64.28	12	56	6.97	49.78	12

Total yield per house—
3721 lb. 1 oz.

Total yield per house—
3830 lb. 3 oz.

TABLE IX

BLOCK C

VARIETY—E.S.5 *Horse manure applied: no fertiliser*

Sown 21st December, 1954 *Potted 14th January, 1955* *Planted 1st March, 1955*

HOUSE 1 53.50 tons/acre								HOUSE 2 43.41 tons/acre							
Plot No.	lbs. Per Plant	Tons Per Acre	No. Plants	Plot No.	lbs. Per Plant	Tons Per Acre	No. Plants	Plot No.	lbs. Per Plant	Tons Per Acre	No. Plants	Plot No.	lbs. Per Plant	Tons Per Acre	No. Plants
28	10.32	73.71	4	29	10.12	72.28	4	28	8.36	59.71	4	29	7.48	53.42	4
27	7.07	50.50	8	30	6.62	47.28	8	27	6.69	47.78	8	30	4.28	30.57	8
26	7.04	50.28	8	31	6.99	49.92	8	26	5.67	40.50	8	31	4.60	32.85	8
25	6.83	48.78	8	32	6.43	45.92	8	25	6.50	46.42	8	32	5.51	39.36	8
24	6.43	45.92	8	33	6.57	46.92	8	24	5.41	38.64	8	33	4.95	35.36	8
23	6.93	49.50	8	34	6.09	43.50	8	23	5.58	39.85	8	34	4.82	34.43	8
22	7.47	53.35	8	35	6.57	46.92	8	22	5.70	40.71	8	35	5.17	36.92	8
21	7.28	52.00	8	36	6.25	44.64	8	21	4.89	34.92	8	36	5.33	38.07	8
20	7.21	51.50	8	37	7.07	50.50	8	20	4.78	34.14	8	37	5.61	40.07	8
19	8.45	60.35	8	38	6.36	45.42	8	19	5.63	40.21	8	38	4.84	34.57	8
18	7.45	53.21	8	39	7.98	57.00	8	18	5.75	41.07	8	39	4.97	35.50	8
17	8.40	60.00	8	40	7.07	50.50	8	17	8.74	41.00	8	40	5.75	41.07	8
16	8.43	60.21	8	41	6.38	45.57	8	16	5.83	41.64	8	41	6.07	43.35	8
15	7.94	56.71	8	42	7.42	53.00	8	15	5.64	40.28	8	42	5.96	42.57	8
14	9.10	65.00	8	43	8.46	60.42	8	14	6.31	45.07	8	43	6.22	44.42	8
13	9.14	65.28	8	44	8.29	59.21	8	13	6.03	43.07	8	44	5.63	40.21	8
12	7.68	54.85	8	45	7.45	53.21	8	12	6.86	49.00	8	45	5.48	39.14	8
11	8.07	57.64	8	46	6.68	47.71	8	11	6.52	46.56	8	46	5.29	37.78	8
10	8.48	60.57	8	47	5.72	40.85	8	10	6.37	45.50	8	47	5.25	37.50	8
9	8.57	61.21	8	48	5.61	40.07	8	9	6.07	43.35	8	48	6.65	47.50	8
8	8.71	62.21	8	49	6.43	45.92	8	8	6.06	43.28	8	49	5.24	37.42	8
7	8.25	58.92	8	50	6.58	47.00	8	7	7.20	51.42	8	50	6.80	48.57	8
6	6.81	48.64	8	51	6.63	47.35	8	6	7.39	52.78	8	51	6.39	45.64	8
5	7.82	55.85	8	52	7.39	52.78	8	5	8.56	61.14	8	52	6.53	46.64	8
4	7.70	55.00	8	53	7.50	53.57	8	4	7.51	53.61	8	53	6.65	47.50	8
3	7.34	52.42	8	54	7.70	55.00	8	3	7.18	51.28	8	54	6.65	47.50	8
2	8.96	64.00	8	55	7.66	54.71	8	2	7.14	51.00	8	55	7.34	53.42	8
1	8.66	61.85	12	56	8.40	60.00	12	1	7.12	50.85	12	56	6.91	49.35	12

Total yield per house—
3355 lb. 14 oz.

Total yield per house—
2723 lb. 1 oz.

TABLE IX—*continued*

BLOCK C

VARIETY E.S.5 *Horse manure applied: no fertiliser*

Sown 21st December, 1954 *Potted 14th January, 1955* *Planted 1st March, 1955*

HOUSE 3 51.50 tons/acre								HOUSE 4 48.27 tons/acre							
Plot No.	lbs. Per Plant	Tons Per Acre	No. Plants	Plot No.	lbs. Per Plant	Tons Per Acre	No. Plants	Plot No.	lbs. Per Plant	Tons Per Acre	No. Plants	Plot No.	lbs. Per Plant	Tons Per Acre	No. Plants
28	9.00	64.28	4	29	8.37	59.78	4	28	8.90	63.57	4	29	10.95	78.21	4
27	6.64	47.42	8	30	5.57	39.78	8	27	5.44	38.85	8	30	6.31	45.07	8
26	6.41	45.78	8	31	6.74	48.14	8	26	5.90	42.14	8	31	6.24	44.57	8
25	7.61	54.35	8	32	5.88	42.00	8	25	7.02	50.14	8	32	6.37	45.50	8
24	6.76	48.28	8	33	4.92	35.14	8	24	5.93	42.35	8	33	6.69	47.78	8
23	6.36	45.42	8	34	5.43	38.78	8	23	6.61	47.21	8	34	6.57	46.92	8
22	6.39	45.64	8	35	7.50	53.57	8	22	7.19	51.35	8	35	6.92	49.42	8
21	7.36	52.57	8	36	7.11	50.78	8	21	6.31	45.07	8	36	6.10	43.57	8
20	6.60	47.14	8	37	7.85	56.07	8	20	6.30	45.00	8	37	6.19	44.21	8
19	6.82	48.71	8	38	7.67	54.78	8	19	6.85	48.92	8	38	5.98	42.71	8
18	7.89	56.35	8	39	8.43	53.07	8	18	6.50	46.42	8	39	7.18	51.28	8
17	8.03	57.35	8	40	8.07	57.64	8	17	6.93	49.50	8	40	7.02	50.14	8
16	6.96	49.71	8	41	7.66	54.71	8	16	7.03	50.21	8	41	7.71	55.07	8
15	7.12	50.85	8	42	7.66	54.71	8	15	7.50	53.57	8	42	7.03	50.21	8
14	6.73	48.07	8	43	8.18	58.42	8	14	6.53	46.64	8	43	6.92	49.42	8
13	6.45	46.07	8	44	6.81	48.64	8	13	6.54	46.71	8	44	5.90	42.14	8
12	7.39	52.78	8	45	7.73	55.21	8	12	6.36	45.42	8	45	6.58	47.00	8
11	6.33	45.21	8	46	8.32	59.42	8	11	7.19	51.35	8	46	5.89	42.07	8
10	5.98	42.71	8	47	6.80	48.57	8	10	6.65	47.50	8	47	6.51	46.50	8
9	7.23	51.64	8	48	7.27	51.93	8	9	6.64	47.42	8	48	6.18	44.14	8
8	7.55	53.92	8	49	7.41	52.92	8	8	7.00	50.00	8	49	6.86	49.00	8
7	7.62	54.42	8	50	7.00	50.00	8	7	7.21	51.50	8	50	7.30	62.14	8
6	7.00	50.00	8	51	7.61	54.35	8	6	7.57	54.07	8	51	6.69	47.78	8
5	7.21	51.50	8	52	7.32	52.28	8	5	6.88	49.14	8	52	6.27	44.78	8
4	7.18	51.28	8	53	8.00	57.14	8	4	5.97	42.64	8	53	6.59	47.07	8
3	7.42	53.00	8	54	7.14	51.00	8	3	6.92	49.42	8	54	7.03	50.21	8
2	7.96	56.85	8	55	8.10	57.85	8	2	7.36	52.57	8	55	6.80	48.57	8
1	7.83	55.92	12	56	8.59	61.35	12	1	7.51	53.64	12	56	7.75	55.35	12

Total yield per house—
3229 lb. 10 oz.

Total yield per house—
3028 lb. 5 oz.

TABLE X

BLOCK D HOUSE 1

SPACING EXPERIMENT

Variety—Potentate *Manure and complete fertiliser added*

Sown December 20th, 1954

Potted January 16th, 1955

Planted February 27th, 1955

	Total Per Plot	lbs. per square yard	Tons per Acre	Plot No.		Total Per Plot	lbs. per square yard	Tons per Acre	
C	lb. oz. 587. 0	49.49	106.93	10	11	lb. oz. 561. 6	47.33	102.26	A
D	518. 9	43.72	94.46	9	12	651. 4	47.32	102.24	C
A	564. 8	47.59	102.82	8	13	454. 3	38.29	82.73	B
B	475.14	40.12	86.68	7	14	621. 2	52.37	113.15	E
E	549.14	46.36	100.17	6	15	537. 9	45.32	97.92	D
D	517. 1	43.59	94.18	5	16	603. 7	50.88	109.93	A
C	613.14	51.75	111.81	4	17	592. 5	49.94	107.90	E
E	569. 2	47.98	103.67	3	18	445. 2	37.53	81.09	B
B	405. 2	34.16	73.81	2	19	517. 6	43.62	94.24	D
A	564.12	47.61	102.87	1	20	583. 3	49.17	106.24	C

	Total	Tons Per Acre	
A	lb. oz. 2294. 1	104.46	= 16,000 plants per acre. Normal spacing
B	1880. 5	85.62	= 8,000 plants per acre. Half Spacing
C	2345. 5	106.81	= 24,000 plants per acre. 12″ instead 14″ between plants in row
D	2090. 9	95.22	= as A half stopped at 5th truss and removed
E	2332. 7	106.23	= as D but shoot trained from adjacent plant into vacant space

(c) Carnations

It was planned to lay out the three carnation houses so that there were 4 rows of six beds in each house, the beds being 15 feet long and 4 feet 10 inches wide, each holding 144 plants.

In the first instance the beds are raised and have been placed directly on the floor of the glasshouse without any attempt at isolation by bricks or tiles.

The stock plants, some 8,000 in all, were very generously presented to us by Mr. C. J. Horwood. All the cuttings were not forthcoming at once; they were rooted as they arrived and planted out when ready. House 3 was planted 18/4/1955, House 2 6/5/1955 and part of House 1 16/8/1955.

TABLE XI

BLOCK D HOUSE 2

SPACING EXPERIMENT

Variety—E.S.5 *Manure and complete fertiliser added*

Sown December 20th, 1954

Potted January 14th, 1955

Planted February 27th, 1955

	Total Per Plot	lbs. per square yard	Tons per Acre	Plot No.		Total Per Plot	lbs. per square yard	Tons per Acre	
C	lb. oz. 394.14	33.29	71.94	10	11	lb. oz. 448. 2	37.78	81.64	A
D	402.14	33.97	73.39	9	12	445. 1	37.53	81.08	C
A	462. 1	38.96	84.17	8	13	349. 7	29.46	63.66	B
B	385.12	32.52	70.28	7	14	430. 4	36.28	78.38	E
E	463. 2	39.05	84.37	6	15	392. 2	33.06	71.44	D
D	430.15	36.33	78.51	5	16	390. 4	32.90	71.09	A
C	436.14	36.83	79.59	4	17	412.10	34.79	75.17	E
E	402.11	33.95	73.36	3	18	344. 3	29.02	62.70	B
B	324. 2	27.33	59.05	2	19	429.11	36.23	78.28	D
A	423.14	35.74	77.22	1	20	475.13	40.12	86.68	C

	Total	Tons Per Acre	
A	lb. oz. 1724. 5	78.53	= 16,000 plants per acre. Normal spacing
B	1403. 8	63.91	= 8,000 plants per acre. Half spacing
C	1752.10	79.82	= 24,000 plants per acre. 12″ instead 14″ between plants in row
D	1655.10	75.40	= as A half stopped at 5th truss and removed
E	1708.11	77.82	= as D. but shoot trained from adjacent plant into vacant space

It was hoped to start a nutrition experiment in 1956, but when the plants had established themselves it seemed advisable to make a special attempt to produce batches of young plants more uniform in character than is found in commerce, so that during the course of the experiments slight differences due to different treatments can be detected. In the first instance this applies only to William Sim, Northland and Ashington Pink.

In starting the crop the soil was well dug, limed 12 cwts hydrated lime per acre and flooded to wet the sub-soil. Horse manure at the rate of 30 tons per acre was dug into the top 10 inches, followed by hoof and horn and bone meal each at the rate of 12 cwts per acre.

Beds were marked out, surrounded by 7 inch western red cedar boards and filled up with soil from the paths. This in turn was given 30 tons short horse manure per acre. Lime, 8 cwts per acre, sulphate of potash, 5 cwts per acre, bone meal, 20 cwts per acre and hoof and horn 20 cwts per acre, were mixed into the top 8 inches very thoroughly.

TABLE XII

BLOCK D HOUSE 4

CULTURAL TRIAL

Variety—Potentate *Manure and Complete fertiliser added*

Sown December 20th, 1954

Potted January 16th, 1955

Planted February 28th, 1955

40 plants per pot

	Total Per Plot	Average Per Plant	Tons Per Acre	Plot No.		Total Per Plot	Average Per Plant	Tons Per Acre	
	lb. oz.					lb. oz.			
H	517. 2	12.92	92.27	12	13	568.10	14.21	101.49	F
F	554. 6	13.95	99.63	11	14	570. 6	14.25	101.77	G
I	548.15	13.72	97.99	10	15	565. 0	14.12	100.85	H
G	501.10	12.54	89.56	9	16	553. 7	13.83	98.77	I
I	485. 5	12.13	86.63	8	17	555.14	13.89	99.20	G
F	500. 4	12.50	89.27	7	18	492. 1	12.30	87.85	H
H	465. 9	11.63	83.03	6	19	505.10	12.64	90.27	F
G	539. 7	13.48	96.27	5	20	519. 9	12.98	92.70	I
G	482.14	12.07	86.20	4	21	472. 2	11.80	84.28	H
F	492. 3	12.30	87.85	3	22	489. 1	12.22	87.28	I
I	498. 7	12.46	88.99	2	23	498.15	12.47	89.06	F
H	452.15	11.32	80.85	1	24	515. 3	12.87	91.92	G

	Total	Tons Per Acre	
	lb. oz.		
F	3120. 0	92.84	= Control
G	3165. 6	94.19	= All side shoots removed before they have become 1" long
H	2964.13	88.23	= All shoots below 2nd truss allowed to grow to 12" before cutting out. All other laterals taken out before they have grown 1"
I	3094.12	92.09	= All side shoots removed except the one below the truss. This left in and stopped after two leaves

During the day prior to planting, the following mixture in the form of a fine powder was spread evenly over the surface at the rate of 1oz. per square yard and pricked into the top 3 inches. It consisted of:—

Sulphate of ammonia 1 part
Nitrate of potash 1 part
Hoof and horn meal 2 parts
Bone meal 2 parts

The results of these trials are given as numbers of flowers per plot in Tables XIII and XIV.

TABLE XIII

HOUSE E.2

Plot	Date 1954	Variety	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	July	Total	Total Number of blooms per plot
1	Feb. 16th	Northland ...	—	—	—	—	—	—	0.0	0.1	0.1	1.2	2.4	2.2	6.0	866
2	Dec. 8th	William Sim ...	—	—	—	—	0.1	0.4	0.6	0.8	0.8	1.9	1.9	2.5	9.0	1302
3	Feb. 2nd	Northland ...	—	—	—	—	—	—	0.0	0.1	0.3	1.6	2.0	2.3	6.3	903
4	Dec. 1st	William Sim ...	—	—	—	—	0.1	0.4	0.6	0.7	0.8	1.9	2.2	1.6	8.3	1179
5	Dec. 1st	Ashington Pink ...	—	—	—	—	0.1	0.6	0.9	0.9	0.6	0.8	3.3	4.0	11.2	1609
6	Dec. 1st	Ashington Pink ...	—	—	—	—	0.2	1.0	1.2	0.9	0.7	0.6	2.3	4.7	11.6	1665
7	Aug. 12th	March. of Headfort	0.1	0.8	1.9	1.8	0.7	0.5	0.3	0.5	0.5	0.9	1.7	3.3	13.0	1926
		Ashington Pink ...	0.1	1.4	2.4	1.4	0.8	1.0	0.5	0.3	0.2	0.3	1.9	5.5	15.8	
		E. F. Guba ...	0.1	0.4	0.6	0.9	1.1	1.2	0.8	0.6	0.6	1.5	2.2	2.5	12.5	
		Kobenhavn ...	0.1	0.7	1.7	1.3	1.0	0.5	0.8	0.7	0.3	0.6	1.5	3.3	12.5	
8	Aug. 15th	Topsy	0.8	1.7	2.1	1.3	1.0	0.7	0.8	5.8	0.1	0.3	1.1	4.5	20.2	2043
		William Sim ...	0.2	0.8	1.9	0.9	0.5	0.6	0.5	0.5	0.8	0.9	2.1	3.9	13.6	
9	Aug. 8th	White Sim ...	0.6	1.3	1.5	0.9	0.5	0.8	0.8	0.5	0.6	0.6	1.8	4.5	14.4	2076
10	Aug. 24th	William Sim ...	0.1	0.5	1.7	0.9	0.5	0.7	0.5	0.8	0.6	0.9	1.8	3.5	12.5	1789
11	Jan. 1st	Johanna Sim ...	—	—	—	—	—	0.7	0.5	0.5	0.5	2.2	2.5	4.2	11.1	1284
		Northland ...	—	—	—	—	—	1.0	0.9	0.9	0.3	1.0	1.5	2.6	8.2	
12	Aug. 1st	William Sim ...	0.1	1.2	2.1	1.0	0.6	0.7	0.4	0.5	0.7	1.5	2.4	3.8	15.0	2146
13	Aug. 8th	White Maytime ...	2.3	3.0	2.3	1.1	0.7	0.7	0.4	0.5	0.5	2.3	4.9	5.5	24.2	2732
		Maytime	1.9	2.1	1.6	0.7	0.6	0.4	0.3	0.3	0.2	1.6	3.0	3.2	15.9	
		Sid. Littlefield ...	1.7	2.3	2.3	1.3	0.8	0.7	0.9	0.6	0.6	1.4	0.9	3.5	17.0	
14	Aug. 8th	William Sim ...	0.3	0.9	2.1	1.1	0.7	0.6	0.5	0.5	0.5	1.7	2.5	4.3	15.7	2240
15	Aug. 10th	Ashington Pink ...	0.4	2.4	2.6	1.4	0.7	0.8	0.6	0.4	0.3	1.0	2.0	6.5	19.1	2744
16	Aug. 10th	William Sim ...	0.2	1.2	2.4	1.0	0.6	0.7	0.5	0.4	0.6	1.6	2.2	4.9	16.3	2332
17	Aug. 12th	Ashington Pink ...	0.9	2.4	2.1	1.4	0.7	0.8	0.6	0.5	0.4	0.7	2.4	6.4	19.3	2769
18	Aug. 8th	William Sim ...	0.5	1.1	1.7	0.9	0.6	0.6	0.5	0.5	0.7	1.6	1.9	4.4	15.0	2166
19	Aug. 15th	Ashington Pink ...	0.3	1.4	2.7	1.2	0.8	0.8	0.6	0.4	0.3	0.5	1.8	6.0	16.8	2428
20	Aug. 9th	William Sim ...	0.4	1.0	2.0	0.9	0.6	0.5	0.4	0.5	0.9	2.0	2.2	3.3	14.7	2107
21	Sept. 21st	Northland ...	—	0.1	0.9	0.6	1.0	1.1	0.8	0.7	0.5	0.8	1.1	2.6	10.2	1473
22	Sept. 5th	Northland ...	—	0.1	1.3	0.9	0.7	1.1	0.9	0.6	0.6	0.9	1.3	3.0	11.4	1649
23	Sept. 5th	Northland ...	—	0.1	1.1	0.7	0.8	1.1	0.9	0.8	0.5	0.9	1.2	2.9	11.0	1598
24	Sept. 12th	Northland ...	—	0.2	1.5	0.9	0.8	1.0	0.7	0.8	0.5	0.8	1.4	3.0	11.6	1677

TABLE XIV

HOUSE E.3

Plot	Date 1954	Variety	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	July	Total	Total Number of blooms per plot
1	Aug. 10th	Ashington Pink ...	1.5	3.1	2.6	1.2	0.5	0.5	0.4	0.3	0.2	0.5	1.7	6.6	19.1	2744
2	Aug. 8th	White Sim ...	1.5	1.5	1.7	1.1	0.5	0.6	0.4	0.3	0.2	0.6	2.4	5.3	16.1	2323
3	Aug. 8th	Ashington Pink ...	1.7	3.0	2.1	0.7	0.5	0.6	0.3	0.3	0.2	0.5	1.6	6.6	18.1	2604
4	Aug. 8th	White Sim ...	2.0	1.2	1.5	0.9	0.6	0.7	0.6	0.6	0.4	0.9	2.3	5.7	17.4	2496
5	Aug. 8th	Ashington Pink ...	2.0	3.2	2.2	1.2	0.6	0.6	0.4	0.3	0.2	0.4	1.4	6.7	19.2	2775
6	Aug. 8th	White Sim ...	1.9	1.3	1.5	1.4	0.7	0.7	0.5	0.4	0.4	1.1	2.1	5.4	17.4	2497
7	Aug. 8th	Ashington Pink ...	2.0	3.0	2.2	1.2	0.5	0.6	0.4	0.3	0.2	0.6	1.7	6.4	19.1	2743
8	Aug. 29th	Northland ...	0.1	1.9	2.3	1.2	0.7	0.3	0.2	0.3	0.2	0.6	1.6	4.1	13.5	1940
9	Aug. 8th	Ashington Pink ...	2.4	3.0	2.1	1.4	0.6	0.6	0.4	0.2	0.2	0.6	1.7	8.8	22.0	3182
10	Aug. 28th	Northland ...	0.1	1.9	2.5	1.4	0.8	0.6	0.5	0.3	0.3	0.8	1.7	3.8	14.7	2095
11	Aug. 8th	March. of Headfort	1.8	3.2	2.1	0.9	0.5	0.3	0.3	0.5	0.3	0.9	2.6	4.8	18.2	2553
	Aug. 8th	Heather Pink ...	1.9	3.4	1.8	0.5	0.5	0.3	0.2	0.3	0.3	0.5	2.4	4.6	16.7	
	Aug. 8th	Apollo	1.6	2.9	1.8	0.5	0.5	0.4	0.3	0.2	0.4	2.0	2.7	4.8	18.1	
12	Aug. 8th	Johanna Sim ...	1.2	2.2	1.8	0.9	0.5	0.7	0.5	0.6	0.7	1.3	1.9	4.5	16.8	2367
		Crowley's Sim ...	1.2	2.2	1.6	0.8	0.6	0.4	0.3	0.5	0.5	1.6	2.8	3.8	16.3	
13	Aug. 8th	Aphrodite ...	1.6	2.4	1.4	0.7	0.4	0.5	0.5	0.6	0.2	0.4	1.5	5.3	15.5	2408
		E. F. Guba ...	1.6	2.4	2.8	2.0	1.0	0.6	0.4	0.2	0.3	1.5	2.0	3.2	18.0	
14	Aug. 8th	Midas	2.8	1.1	1.4	0.4	0.3	0.2	0.3	0.6	0.7	1.6	2.8	3.7	15.9	2514
		Ashington Pink ...	1.4	2.3	2.7	1.0	0.6	0.5	0.5	0.5	0.2	0.8	1.9	6.7	19.1	
15	Aug. 8th	Monty's Pink ...	3.1	3.7	1.6	0.7	0.4	0.4	0.5	0.9	1.4	2.9	3.5	3.6	22.7	3005
		Asa Thor ...	1.5	3.7	2.7	0.9	0.6	0.4	0.4	0.6	0.6	1.4	1.5	4.6	18.9	
16	Aug. 8th	Kobenhavn ...	0.5	2.5	2.6	1.2	0.6	0.4	0.4	0.4	0.4	0.5	1.4	4.2	15.1	2176
17	Aug. 8th	Asa Thor ...	0.5	3.6	2.6	1.2	0.6	0.4	0.4	0.4	0.5	0.9	1.5	5.2	17.8	2569
18	Aug. 10th	Topsy	1.7	3.3	2.1	0.6	0.4	0.3	0.3	0.3	0.3	0.6	1.5	5.8	17.2	2496
19	Aug. 26th	Northland ...	0.1	1.6	2.1	1.2	0.8	0.5	0.5	0.5	0.3	0.8	1.6	3.4	13.4	1920
20	Aug. 8th	William Sim ...	1.6	1.5	1.7	0.8	0.4	0.6	0.5	0.4	0.6	1.1	2.4	4.8	16.4	2365
21	Aug. 26th	Northland ...	0.1	1.4	2.4	1.2	0.8	0.6	0.4	0.5	0.4	0.7	1.2	3.8	13.5	1916
22	Aug. 8th	William Sim ...	2.1	1.4	1.5	0.9	0.4	0.6	0.4	0.4	0.4	1.1	2.4	4.3	15.9	2295
23	Aug. 26th	Northland ...	0.1	1.2	2.4	1.2	0.8	0.6	0.5	0.5	0.3	0.7	1.2	4.0	13.5	1905
24	Aug. 8th	William Sim ...	1.8	1.7	1.6	0.7	0.5	0.6	0.5	0.5	0.5	1.0	2.3	5.0	16.7	2404

(d) Tomato breeding

Blocks F and G consisting of pairs of houses each 110 feet long and 29 feet wide were very generously presented to the Institute by the Tomato and Cucumber Marketing Board on the understanding that they will be used for the purpose of tomato breeding, attempting in the first instance to produce a tomato possessing all the good qualities of Potentate and none of its defects. Permission to accept this gift was granted by the Agricultural Research Council, who also provided a plant breeder on the understanding that he should devote all his attention to practical breeding and that research in the science of genetics must not be attempted here, but be left to those research stations already recognised as centres for genetical research.

The provision of these four glasshouses made it possible to continue and extend the work of tomato breeding started at Cheshunt many years ago and which produced the well-known varieties, Experimental Station No. 1 (E.S.1), Leaf Mould Resister No. 1 (L.M.R.1.) and E.S.5.

In the early work, attention had been devoted to varieties which were disease resistant and which produced fruit of high quality and good flavour.

In 1951, at the request of the Chairman of the Tomato and Cucumber Marketing Board, the object of the work was changed a little. A considerable number of strains of Potentate and also similar varieties were tried side by side at Cheshunt, but none of them proved better than the Cheshunt selection of Potentate, as produced by the Market Growers' Seed Association at Hassocks. The following year many crosses were made using Potentate as both the female and male parent.

The first crop in block F was planted June 1954; the hybrids were a repetition of those employed at Cheshunt the previous year. As the plants were not planted until June the crop was an unusual one and the results are not recorded here.

In 1955, the soil was thoroughly cultivated and the crop was planted, F1 and F2 on 21st March and G1 and G2 on 27th April. The results are given in Tables XV to XVIII.

TABLE XV

Tomato Hybrids and Varieties
House F.1 1955

Plot	Variety		Crop yield in lbs per plant							Total Tons Per Acre	% Blotchy	% P. & P. & W.	% W.
			May	June	July	Aug.	Sept.	Oct.	Total				
1	Potentate x E.S.5	F.2	0.12	3.61	3.49	3.24	1.44	1.07	13.06	93.28	4.92	26.51	21.28
2	Downes x Potentate	F.2	0.07	8.92	3.32	2.82	0.91	0.75	10.82	77.28	8.56	20.10	26.13
3	Delicious x Potentate	F.2	0.05	2.68	3.21	2.71	0.90	0.80	10.30	73.57	7.68	26.58	21.33
4	Potentate x Radio	F.2	0.05	2.97	3.45	2.35	1.12	0.37	10.81	77.21	9.55	21.42	22.56
5	Potentate x Ailsa Craig ...	F.1	0.11	3.45	3.61	2.78	0.92	0.72	11.60	82.85	6.43	25.95	27.63
6	Potentate x Ailsa Craig ...	F.2	0.06	3.04	3.45	2.75	1.01	0.84	11.16	79.71	7.86	21.14	21.23
7	E.S.1 x Potentate	F.2	0.08	3.21	3.96	3.24	1.11	0.97	12.59	89.92	6.74	23.09	26.38
8	Potentate x E.S.5	F.2	0.09	3.20	3.39	2.93	1.11	1.03	11.76	84.00	5.53	21.15	32.49
9	Potentate x E.S.5	F.3	0.07	3.26	3.18	2.20	0.87	0.67	10.25	73.21	9.18	20.72	24.14
10	Fordhook hybrid x Potentate	F.2	0.05	3.49	3.92	2.80	0.76	0.57	11.62	83.00	3.14	13.05	11.15
11	Downes Seedling	—	—	—	1.76	2.68	2.50	0.76	0.78	8.65	61.78	3.55	10.03	35.62
12	Delicious	—	—	—	1.85	3.36	2.62	1.19	1.13	10.18	72.71	7.72	23.85	25.11
13	E.S.1	—	0.02	2.56	3.78	3.08	0.92	0.47	10.89	77.78	2.50	27.78	36.68
14	Wheatleys	—	—	—	1.86	3.33	3.13	1.19	0.93	10.51	75.07	3.36	21.02	35.72
15	Potentate	—	0.03	3.17	3.60	2.41	1.05	0.90	11.18	79.85	20.69	13.71	8.11
16	E.S.5	—	0.09	3.02	3.99	3.40	0.85	0.56	11.90	85.00	3.69	29.63	28.99
17	Radio	—	—	—	1.64	4.24	3.33	1.30	0.60	11.13	79.50	5.49	31.38	28.73
18	Potential	—	0.02	2.20	3.66	3.45	1.04	0.76	11.14	79.57	4.04	43.22	25.45
19	Ailsa Craig	—	0.08	2.79	3.69	3.44	0.91	0.67	11.60	82.85	1.51	29.09	37.50
20	L.M.R.I.	—	0.07	2.56	3.11	3.27	1.41	1.73	12.14	86.71	2.01	30.15	25.99

TABLE XVI

Tomato Hybrids

House F.2 1955

Plot	Variety		Crop yield in lbs per plant							Total Tons Per Acre	% Blotchy Ripening	% P. & P. & W.	% W.
			May	June	July	Aug.	Sept.	Oct.	Total				
1	Potentate x Potential	F.2	0.19	3.59	3.41	3.59	1.29	1.77	13.86	98.98	6.59	32.15	15.41
2	Potentate x Potential	F.2	0.16	2.87	2.93	3.02	1.17	1.52	11.70	83.56	10.09	34.38	15.71
3	Potentate x Potential	F.3	0.09	3.11	3.39	2.53	1.01	1.52	11.68	83.42	7.64	30.98	20.84
4	Potential x Potentate	F.2	0.10	3.33	3.17	2.50	1.09	1.42	11.62	82.99	5.91	37.86	19.53
5	Potential x Potentate	F.3	0.07	2.70	3.28	2.76	1.18	1.00	11.00	78.56	6.00	28.10	24.52
6	Potentate x Delicious	F.2	0.18	3.18	3.35	3.09	1.25	1.30	12.36	88.27	7.20	29.18	20.07
7	Potentate x Delicious	F.1	0.19	3.02	2.77	3.33	1.09	1.29	11.71	83.63	9.38	31.01	19.02
8	Delicious x Potentate	F.2	0.15	2.90	3.01	3.15	1.02	1.39	11.64	83.13	3.95	32.68	27.47
9	Delicious x Potentate	F.3	0.06	2.25	3.25	2.93	1.10	1.07	10.68	76.28	4.40	32.76	36.35
10	Potentate x L.M.R.1.	F.1	0.10	3.16	3.08	2.97	0.87	1.11	11.31	80.77	5.66	27.89	30.41
11	Potentate x Wheatleys ...	F.1	0.05	3.21	2.95	2.83	2.97	1.47	11.50	82.13	4.10	28.21	25.29
12	Potentate x Wheatleys ...	F.2	0.08	2.99	3.03	3.01	1.35	1.53	12.01	85.77	4.50	26.99	23.14
13	Potentate x Kondine	F.2	0.13	2.99	2.57	2.85	1.13	1.20	10.89	77.77	7.38	22.96	18.85
14	Wheatleys x Potentate ...	F.2	0.05	3.06	3.35	2.67	0.84	1.20	11.18	79.86	4.19	28.46	28.47
15	Wheatleys x Potentate ...	F.1	0.07	2.32	2.77	2.65	1.08	0.95	9.86	70.42	3.04	35.99	30.23
16	Potentate x E.S.1	F.1	0.25	3.05	3.51	2.65	0.95	0.87	11.31	80.78	3.55	35.27	29.47
17	Potentate x E.S.1	F.2	0.23	2.65	3.11	2.60	1.03	1.04	10.69	76.35	5.34	33.36	22.22
18	Kondine x Potentate	F.1	0.29	2.73	2.95	2.40	0.85	1.10	10.33	73.79	11.48	26.60	11.05
19	E.S.1 x Potentate	F.2	0.11	3.01	3.52	2.57	1.08	0.88	11.21	80.07	6.15	27.30	25.99
20	E.S.1 x Potentate	F.3	0.09	2.96	3.32	2.89	0.99	0.95	11.20	80.00	1.04	28.97	27.27
21	Potentate x Wheatleys ...	F.1	0.11	2.78	3.22	2.54	0.69	1.21	10.56	75.43	9.07	34.84	16.72
22	Potentate x Downes	F.2	0.18	3.36	3.47	2.96	1.06	1.08	12.11	86.24	10.20	29.00	17.55

TABLE XVII

House G.1 1955

Plot	Variety		Crop yield in lbs. per plant						Total Tons Per Acre	% Blotchy Ripening	% P. & P. & W.	% W.
			June	July	Aug.	Sept.	Oct.	Total				
1	L.M.R.1.	—	0.10	3.22	2.99	2.23	1.64	9.49	67.78	7.77	38.33	21.78
2	Potentate x Downes	F.1	0.25	4.14	2.05	1.79	1.21	9.45	67.51	4.39	28.64	25.10
3	Potentate x Best of All ...	—	0.03	3.37	2.49	1.08	1.21	8.19	58.49	18.07	18.69	10.65
4	Potentate x L.M.R.1.	F.2	—	2.95	2.87	1.50	1.45	8.80	62.86	3.29	43.82	22.51
5	Potentate x L.M.R.1.	F.1	0.11	3.39	2.59	1.40	1.23	8.74	62.43	4.33	33.69	27.40
6	Potentate x Delicious	F.2	0.01	3.03	3.25	1.38	1.04	8.73	62.41	13.60	29.31	17.57
7	Potentate x Delicious	F.1	0.06	3.67	3.22	1.25	1.05	9.28	66.29	8.12	35.84	21.10
8	Delicious	—	—	2.41	4.10	1.20	1.05	8.78	62.71	6.31	44.94	26.16
9	Potential	—	—	2.27	3.02	1.16	1.52	8.00	57.14	6.56	42.54	26.17
10	Potentate x Potential	F.2	0.04	3.19	3.15	1.37	1.37	9.08	64.86	7.02	29.18	22.67
11	Potentate x Potential	F.1	—	2.97	3.22	1.29	1.21	8.98	64.14	7.75	32.29	24.02
12	Potentate	—	—	3.21	2.99	1.31	1.55	9.08	64.86	12.46	23.63	12.39
13	Up-to-date	—	—	2.55	2.67	2.01	1.21	8.46	60.43	22.62	9.68	11.11
14	Kondine x Potentate	F.1	0.01	3.51	2.15	1.82	1.30	8.80	62.86	12.27	20.49	9.97
15	Potentate x Kondine	F.2	0.03	3.55	2.16	1.77	1.05	8.58	61.29	15.29	21.67	11.24
16	E.S.1	—	0.01	2.93	3.24	1.85	1.13	9.18	65.57	1.13	28.86	44.33
17	Potentate x E.S.1...	F.1	0.03	3.42	3.24	1.64	0.94	9.29	67.37	9.26	31.57	25.43
18	Potentate x E.S.1...	F.2	0.01	2.94	3.01	1.50	1.51	8.97	64.07	9.49	29.12	20.99
19	Swedish Variety	—	0.07	3.53	2.25	1.69	1.18	8.83	63.07	6.78	28.98	12.33
20	Potentate x E.S.5...	F.2	0.03	3.11	2.47	1.63	1.30	8.55	61.07	8.62	23.35	27.66
21	Ware Cross	—	0.07	3.00	2.98	1.73	1.39	9.19	65.64	4.20	29.79	17.97
22	Hertford Cross	—	0.15	3.00	3.35	1.66	1.47	9.66	69.00	3.59	31.62	20.68
23	Potentate x Downes	F.2	0.04	3.06	3.01	1.90	1.37	9.39	67.06	8.15	23.80	20.68
24	E.S.5	—	0.04	3.51	3.27	2.47	1.58	10.90	77.85	0.58	27.05	25.48

TABLE XVIII

Tomato Hybrids

House G.2 1955

Plot	Variety		Crop yield in lbs. per plant						Total Tons Per Acre	% Blotchy Ripening	% P. & P. & W.	% W.
			June	July	Aug.	Sept.	Oct.	Total				
1	E.S.5	—	0.19	4.03	3.02	2.47	1.86	11.59	82.79	1.43	31.33	20.79
2	Potentate x Downes	F.2	0.11	3.07	2.87	1.73	1.54	9.34	66.70	7.03	22.76	21.73
3	Hertford Cross	—	0.18	3.05	3.17	1.71	1.85	9.90	70.71	5.71	30.71	20.83
4	Ware Cross	—	0.10	3.19	3.12	1.79	1.72	9.93	70.93	5.42	24.47	26.49
5	Potentate x E.S.5...	F.2	0.06	2.95	3.02	1.30	1.73	9.07	64.79	3.59	21.08	29.14
6	Swedish Variety	—	0.11	3.86	2.76	1.39	1.59	9.72	69.43	7.04	27.11	12.02
7	Potentate x E.S.1...	F.2	0.02	3.34	3.07	1.70	1.70	9.85	70.36	5.75	28.21	20.63
8	Potentate x E.S.1...	F.1	0.09	3.31	1.56	1.91	1.40	9.29	66.36	2.35	26.09	25.32
9	E.S.1	—	0.03	3.08	3.26	1.69	1.82	9.90	70.71	1.72	22.02	34.90
10	Potentate x Kondine	F.2	0.04	3.49	2.70	1.64	1.49	9.43	67.36	12.01	20.27	10.43
11	Potentate x Kondine	F.1	0.01	3.53	3.02	1.50	1.89	9.95	71.07	13.47	21.57	6.78
12	Up-to-date	—	—	—	2.30	3.10	1.52	1.62	8.55	61.07	18.13	13.22	14.18
13	Potentate	—	—	—	2.87	3.12	1.27	1.68	8.97	64.07	14.27	19.53	9.29
14	Potentate x Potential	F.1	0.01	2.05	2.91	1.16	1.16	7.55	53.93	3.78	36.41	25.22
15	Potentate x Potential	F.2	0.03	2.74	3.04	1.19	1.69	8.69	62.07	3.36	33.03	19.58
16	Potential	—	—	—	2.24	3.36	1.11	1.58	8.30	59.28	3.39	48.83	25.39
17	Delicious	—	0.01	2.45	3.78	0.99	1.49	8.71	62.21	5.83	40.23	29.79
18	Potentate x Delicious	F.1	0.03	3.50	3.11	1.09	1.29	9.03	64.50	9.46	31.00	21.57
19	Potentate x Delicious	F.2	0.02	3.25	3.24	1.35	1.66	9.53	68.07	8.95	25.52	15.94
20	Potentate x L.M.R.1.	F.1	0.11	3.10	2.61	1.35	1.40	8.59	61.36	3.16	35.04	25.69
21	Potentate x L.M.R.1.	F.2	0.05	3.27	3.47	1.09	1.98	9.87	70.50	6.16	42.97	19.01
22	Potentate x Best of All	—	0.06	3.59	2.43	1.09	1.40	8.59	61.36	17.97	19.22	11.25
23	Potentate x Downes	F.1	0.15	3.62	2.48	2.04	1.18	9.49	67.78	6.12	28.55	24.83
24	L.M.R.1.	—	0.15	3.34	2.12	2.64	1.75	8.05	57.50	3.67	37.22	18.70

3. Plant Pathology

by

P. H. WILLIAMS

1 Didymella Stem Rot

Laboratory work on the biological factors which influence recolonisation of sterilized and unsterilized soil by *Didymella lycopersici* was continued. The methods employed have included direct observation of the fate of spores added to thin layers of sterilized and unsterilized soil on slides and observations on the effect of soil solution on the germination of spores. Experiments were also started to determine the part played by various fungi, bacteria and actinomycetes in making unsterilized soil unfit for the growth of *D. lycopersici*. Since the results of this work are not yet fully available, it is proposed to publish a fuller account in the next Annual Report.

2 Cucumber Mildew

The work at Cheshunt was continued. New collections of mildew on various weeds were made and prelimimary inoculations on cucumber carried out. The presence of mildew on cucumbers in adjoining houses, however, made it very difficult to avoid accidental contamination of test plants despite the use of plastic covers. New methods of maintaining pure cultures of mildews and of preventing contamination during experimental transfers were therefore sought. It proved possible to grow cucumbers and some other plants in large test tubes on coarse sand moistened with a nutrient solution. The tubes are sterilized in the autoclave and the seeds treated with calcium hypochlorite before sowing in the sterilized tubes. The plants are therefore growing under sterile conditions and with due precautions during transfer, the risk of contamination by other mildews is very small. By adding fresh sterilized nutrient solution aseptically from time to time, the plants can be kept alive for some time and it has been found that the mildew develops satisfactorily under these conditions.

3 Carnation Wilt

Investigations on carnation wilt have been begun. The work is complicated by the fact that several pathogens are involved. Of these *Verticillium cinerescens* and *Fusarium dianthi* have been known for some years. Recently a new bacterial wilt caused by a species of *Erwinia* has veen found in this country. A second bacterial wilt caused by *Pseudomonas caryophylli* has been known for a long time in the United States and may be present in this country although, as it is associated with high temperatures, it is not likely to become widespread here.

The first stage of the investigation, therefore, has been to examine a number of specimens to determine the relative importance of the pathogens. A start has also been made with building up a healthy stock for future work.

4 Mushroom Diseases

When the Mushroom Research Station at Yaxley was closed in October, 1954, Miss Gandy, the microbiologist, was transferred to the National Agricultural Advisory Service Sub-centre at Wye and remained there until the Plant Pathology laboratories at the Glasshouse Crops Research Institute were ready in June 1955. The two phases of her work at Wye and Littlehampton are dealt with separately below.

An investigation was started at Wye into "La France" disease and similar disorders of mushrooms, characterised by death and deformity of sporophores and low yield. Four outbreaks of suspected "La France" disease in crops grown under widely different conditions were investigated. Regular visits were made and the distribution and spread of the affected areas of beds were plotted. Compost,

casing materials and mushrooms were examined but the cause of the disorder was not found. In no case did the symptoms agree in all respects with those described for "La France" disease by Sinden and Hauser ([1]).

Small scale laboratory experiments were carried out using 600-ml beakers filled with moistened sterile spawn. These beakers were then inoculated with material from affected crops and cased with a layer of steam sterilized soil. In some, but not all, cases the disorder was transmitted when beakers were inoculated with soil, compost or water extracts of abnormal sporophores. The descriptions of the four outbreaks and experimental results are published in greater detail elsewhere ([2]).

After transfer two further outbreaks of suspected "La France" disease were examined and material collected. Attempts to carry out further beaker experiments were unsuccessful, conditions in the laboratory being unsuitable for mushroom production. Accordingly further experiments had to be postponed until the erection of the mushroom house was completed.

During the course of this investigation it became increasingly evident that some system of classification of sporophore abnormalities was required if useful descriptions of them were to be obtained. In co-operation with the Chemistry Department a study was made of size and form in normal and abnormal mushroom sporophores.

Pure cultures of mushroom mycelium from abnormal crops and also from commercial spawns were established. Preliminary examinations of these cultures showed that those obtained from crops with suspected "La France" disease grow very slowly and poorly on the agar medium, and the colony generally has a brownish colour. A series of growth rate experiments were planned for the future.

5 Virus Diseases *by R. Howles*

(*a*) *Chemical inactivation of virus in tomato seed*

It was shown in the Annual Report of the Cheshunt Experimental Station for 1954 that if virus infected tomato seed was treated with saturated 2-chlorophenoxyacetic acid for six days the virus content was reduced to a small amount. If the same seed was then washed in water, dried, and placed in water to continue germination it was found that, by the time of incipient germination, there was no virus left. The virus, and probably also the enzymes involved in germination, had been inactivated by means of the acid. Seedlings grown from seed treated in this way were prefectly normal.

The work was repeated as a check and it was confirmed that this procedure completely inactivated the virus.

In further experiments both treated and untreated seed were germinated in soil and the seedlings grown on until they reached the nine foliage leaf stage. There were two hundred plants of each of four varieties, one hundred of each variety grown from treated seed and one hundred from untreated seed. At this stage the intention was to record the number of virus-infected plants but it was found that only one showed signs of infection. There had, however, been larger numbers infected at this stage in similar experiments carried out in previous years.

(*b*) *Chemical treatment of chrysanthemum cuttings infected with chrysanthemum flower-distorting virus*

Treatment No. 1. On each of five consecutive days one hundred potted chrysanthemum cuttings infected with chrysanthemum flower-distorting virus were each given 100-ml of 0.013% solution of 3-chlorophenoxyacetic acid by applying it to the soil.

Treatment No. 2. On each of two consecutive days another one hundred were given 100-ml of 0.013% solution of 2, 4-dichlorophenoxyacetic acid ammonium salt in the same way.

Each plant was tested for virus not less than one month after treatment and those found to be virus-free were retested later. After being retested twice during the ensuing six months, seven plants were found to have been cured by treatment No. 1 and twenty-two by treatment No. 2.

SUMMARY

1. Treatment of virus infected tomato seeds with saturated 2-chlorophenoxyacetic acid for *six* days completely inactivated the virus.

2. Promising results were also obtained upon rooted cuttings of chrysanthemums infected with flower-distorting virus. The application of 3-chlorophenoxyacetic acid and 2,4-dichlorophenoxyacetic acid respectively to the soil resulted in 7% and 22% of the plants being free from the virus after six months.

REFERENCES

[1] Sinden, J. W. and Hauser, E., (1950) Report on Two New Mushroom Diseases. Mushroom Science **1**, 96.

[2] Gandy, D. G., (1955) Some Disorders of Cultivated Mushrooms. Plant Path., **4,** 118–119.

4. Entomology

RED SPIDER MITE (*Tetranychus* spp.)

by

W. J. PARR and C. CROCKER

The question of colour forms has recently come into greater prominence in view of possible differences in resistance to acaricidal treatment which they may exhibit. Also, there can be no doubt that in the past the common red spider mite has been described under many specific names based mainly on colour variations. It seems timely, therefore, to give a brief review of more recent information with regard to colour, synonymy and acaricidal resistance of the Red Spider Mite complex at present available in the literature and from observations carried out both at this Institute and at Cheshunt.

1. Colour forms of summer females

For some years the existance of two distinct colour forms amongst summer females has been observed: a green or yellowish form with a large internal dark trifid spot on each side of the body which hibernates as a bright red mite during winter, and a deeper red or carmine form with more extensive dark markings on each side which may continue to breed slowly throughout the winter at temperatures above 64°F. The eggs of these forms are also distinct—the green females laying pearly white eggs whilst those produced by the carmine females are distinctly brown or reddish.

Ewing (1914) recognised that the colour variants of *T. telarius* were due to primary pigments, to the presence of absorbed chlorophyll or to unexcreted waste products and, in many individuals, to a combination of more than one of these factors. He also found that this complex situation was further influenced by the particular host plant upon which the mites were feeding, and records that the reddish orange colour was most prevalent among adults feeding on red clover, rose, tangerine and violet, whereas the green form was found on a wide variety of plants. (Examination of Plate 2, Fig. 3 of his paper suggests that his reddish orange more nearly resembles the carmine colour illustrated by Pritchard and Baker, Plate 1).

Linke (1953), however, working with green and red summer populations of *T. althaeae* on hops, considers that the colour differences of the female are genetically fixed and cannot be influenced by external factors.

A similar marked difference in colour between two populations was recorded by Neiswander *et al* (1950) working with *T. bimaculatus* in America: that upon roses under glass being of the two-spotted green type whereas those upon bean and tomato were predominantly red or maroon in the adult stage.

At Cheshunt, the green form bred abundantly on tomatoes under glass during the summer, whilst the carmine mite was restricted to carnations, arums and a number of other ornamental plants. At Littlehampton, the latter form appears to be the only one so far established on cucumbers and to a lesser extent on tomatoes; the green form being totally absent. On other local and longer established nurseries, however, the green is the dominant form on these plants. The introduction of the carmine mite into the glasshouses of this Institute was undoubtedly brought about by the transference of infested ornamental plants from Cheshunt. In the instances cited, no reliable morphological differences were found whereby the two forms could be separated and it was thus assumed that they were one and the same species. There is evidence (Neiswander *loc. cit.*) that when transferred from one host plant to another, these forms may, through several generations, undergo colour changes.

When deprived of food, green type females often assume an orange-red colour somewhat similar to that of the hibernating phase. This should not, however, be confused with the much deeper colouration of the actively feeding red form. The colour due to starvation is of a temporary nature and when given suitable food the mites quickly regain their green colour.

2. Synonymy

Considerable confusion has arisen in the synonymy of the common red spider mite due largely to past descriptions, under many specific names, based on colour variations, and to taxonomic work based on unreliable structural characters. Recent cross breeding experiments in America have helped to clarify the position with regard to some of its more complicated aspects.

From the results of these experiments it would seem that at least two species are involved, *T. telarius* L., the active summer females of which are green in colour and which has a world wide distribution in temperate latitudes, and *T. cinnabarinus* Boisduval (1867), the summer females of which are carmine or dark red and which occurs in the more tropical zones and occasionally in Northern glasshouses. The latter species was first described from specimens from France taken in a greenhouse on *Dracaena*, and appears to be the first description of the carmine form.

Pritchard and Baker (1955) retain the Linnaean name *T. telarius* for the common spinning mite and have referred to it many of the names in common use for this species including *urticae* Koch and its form *dianthica* Dosse; *althaeae* von Hanstein and the American *bimaculatus* Harvey. They point out, however, that as employed by them, the name *telarius* represents a polytypic species represented by at least several sub-species or species.

McGregor (1950) described *T. multisetis*, a carmine form with additional setae on tarsus I and Keh (1952) showed that this species would not produce fertile offspring when crossed with *T. bimaculatus* (*telarius*). Davis (1952) secured free interbreeding between *multisetis* and a carmine form of *telarius*. Dosse (1952) described a carmine form of red spider mite on carnations in Germany as *T. urticae* var. *dianthica* which according to Boudreaux (1956) has the same chaetotaxy as *multisetis* and which he considers, as a result of breeding experiments, to be synonymous with *T. cinnabarinus* Bois. Boudreaux also claims that *T. cinnabarinus* is distinct from *T. telarius* as, although the species hybridize freely, the hybrids are sterile. Davis's fertile crosses between *multisetis* and carmine *telarius* must therefore have been in fact between *multisetis* and *cinnabarinus* which are now regarded as co-specific.

In addition to the evidence of cross breeding, Boudreaux (*loc. cit.*) claims that the females of *telarius* and *cinnabarinus* are distinguishable from one another by differences in the detailed structure of the dorsal integument.

Cross breeding experiments are in progress at this Institute to determine whether the green and red forms present in glasshouses in this country are in fact distinct species. Should this prove to be the case, it will necessitate a re-evaluation of their behaviour particularly with regard to host preference and acaricidal resistance.

3. Acaricidal Resistance

It has been shown that several factors apparently influence acaricidal resistance, but unfortunately, in these earlier observations little attempt was made to control conditions other than those under investigation. In view of the complexity of the problems associated with this mite it is abundantly obvious that the validity of the factors enumerated below should be tested again in the near future.

(*a*) *Host*

Neiswander *et al* (1950) observed that *T. bimaculatus* on roses were more resistant than those on beans which in turn were more resistant than those on tomatoes. Earlier, Compton and Kearns (1937) had found that mites from roses were much more resistant to selenium compounds than populations

from snapdragons in tests on cotton cloth. Neiswander (*loc. cit.*) using green *T. bimaculatus* on roses and red forms on beans claimed that the greater acaricidal resistance of the green forms disappeared after three weeks when kept on beans and that the colour difference became less evident. Conversely the red form, kept on roses for 4–5 months, became resistant to selenium and underwent a colour change. Smith and Fulton (1951), however, showed that a resistant strain loses none of its powers of resistance against parathion for a period of 10 months after emigrating to other cultivated plants or weeds even if, during this time, it had no contact with an acaricide. They claim that resistant and non-resistant strains never appear together in the same greenhouse. Cole and Fiske (1955) using red forms of *T. bimaculatus* in comparable tests upon bean plants, found that those reared upon squash were less susceptible to DMC than were those reared exclusively on bean. But mites from either host were equally susceptible to malathion.

(*b*) *Host nutrition*

Garman (1950) finding that mites lost their resistance to parathion when transferred from roses to beans observed that they had, during this period, absorbed large quantities of molybdenum from the beans. He then demonstrated that where plants were grown with the addition of ammonium molybdate there was no alteration in resistance of *T. bimaculatus* to parathion. However, when selenium and molybdenum were supplied at only low levels the mite resistance was intermediate between the control and selenium alone.

(*c*) *Mite population*

Cole and Fiske (1955) could find no significant difference between the resistance of the two colour forms of *T. bimaculatus* in spray and immersion tests of aramite, DMC and TEPP. Green forms were, however, more susceptible to EPN (5% level) and less susceptible to malathion (2% level) when reared on beans.

Dosse (1952) found that *T. urticae* f. *dianthica* (now assumed to be the red form *T. cinnabarinus*) was resistant to E605 but could be controlled by five repeated sprayings with Systox (0.08%). *T. althaeae* (green *T. telarius*) on hops, however, was killed in 24 hours by one application of the latter at a concentration of 0.01–0.03%.

It must be remembered that, as shown by Neiswander *et al* (1950), mite populations subjected to the action of a dilute acaricide for 3–4 generations may develop a partial immunity to that material. Future testing techniques will have to be designed so as to eliminate the variables mentioned above as far as practicable and the question of acaricidal resistance must be investigated both in *T. telarius* and *T. cinnabarinus* as well as their hybrids.

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5. Crop Protection

by

W. H. READ, J. T. HUGHES and R. J. SMITH

1. Didymella Stem Rot

The testing of compounds as eradicants against *Didymella* (*D.lycopersici*) lesions on tomato stems has been continued by the use of the method indicated in the Annual Report for 1953.

None of the numerous compounds applied as pastes to the lesions, obtained by inoculating tomato stems, prevented the growth of the fungus and the eventual death of the plant. Two pastes, however, one containing 10% of the sodium salt of 4-chlorobenzald-α-oxime and the other 10% of the sodium salt of salicylanilide, caused an initial reduction in the rate of development of lesions.

In view of the current interest in the following compounds it is of interest to note that pastes containing 25% of 2-hydroxycinnamic acid and 0.5% of griseofulvin, respectively, proved ineffective.

The application of sprays containing 0.1% griseofulvin, together with a wetting agent, failed to check the development of *Didymella* lesions or to prevent the infection of stem wounds by *Didymella* and subsequent development of lesions.

2. Cucumber Mildew

The comparative values of dusts and high volume sprays containing 2:4-dinitro-6-*sec*octylphenyl crotonate ('Karathane') for the control of cucumber mildew (*Erysiphe cichoracearum*) have been examined. Dusts were not so persistent as sprays and did not eradicate the fungus so effectively as sprays but evidence was obtained that suggests that the application of a 2% dust, at the rate of 15 lbs/acre and at intervals of ten days, was less injurious to cucumbers than the application of sprays (0.012% w/v technical 2:4-dintro-6-*sec*octylphenyl crotonate) at intervals of three weeks, and showed considerable economy of labour when a modern compressed-air dusting appliance was used.

3. The Control of Aphides on Carnations

Preliminary experiments were made to compare the values of γ-BHC (0.012%), parathion (0.01%), malathion (0.02%), demeton-methyl* (as 'Metasystox') (0.05%) and schradan (0.08%) sprays, and demeton-methyl (0.04%) and schradan (0.86%) soil drenches, for the control of aphides (*Myzus persicae*) on carnations. The rate of application of the two systemic insecticides to the soil was $2\frac{1}{2}$ gals/square yard.

The tests were made in June and July on one year old plants in the beds in three large, interconnected houses forming the carnation house block at Rustington. Simultaneous comparative trials, in which certain of the insecticides could be dispersed as aerosols or smokes, were impossible under these circumstances. Each treatment was applied to the plants in five beds, each 67.5 square feet in area, and, with two unimportant exceptions, each insecticide was tried on five carnation varieties—White Sim, William Sim, Ashington Pink, Northland and Asa Thor.

Results were assessed by estimating the population immediately before and 18–20 days after treatment by removing shoots from the plants and counting the living aphides on these.

The best result in these tests was obtained from the soil treatment with demeton-methyl which completely eliminated the aphides. Spraying with schradan or demeton-methyl gave slightly inferior results as did parathion, malathion and γ-BHC sprays. The soil application of schradan gave poor results in these trials but additional work is required to determine the value of the systemic insecticidal compounds under a wide range of climatic and cultural conditions.

*Demeton-methyl is the active material in the proprietary product 'Metasystox.'

Red spider mites (*Tetranychus telarius* L.) were present on only very few of the plants used in these trials but later work has shown that demeton-methyl gave complete control of this pest on carnations when applied to the soil. Spray applications of technical demeton-methyl imparted an unpleasant odour to carnations which persisted for several days; consequently their application to flowering plants is obviously undesirable.

4. The Estimation of Parathion Residues in the Presence of Azobenzene

Azobenzene is used together with parathion in certain commercial smoke generators, not only to increase the pesticidal range and efficiency of the latter but also as a convenient compound which, by readily vapourising, relieves the pressure on the container as the other contents swell on combustion[1]. It is also used alone purely on account of its intrinsic acaricidal properties, and relatively large amounts are present in the mixed azobenzene-parathion type of smoke generators. Azobenzene may therefore occur together with parathion in crop residues causing serious interference in any method of analysis based on reduction followed by diazotisation and coupling[2]. Under such conditions azobenzene is reduced to a mixture containing aniline and/or benzidine which diazotise and couple to form intense blue or reddish dyes with N-naphthyl-ethylene-diamine dihydrochloride.

The above interference would be avoided by using the method for parathion based on hydrolysis to *p*-nitrophenol and direct measurement of the absorbance, at 400–mμ, of the yellow solutions so produced. However, if aqueous alcohol is used as the solvent for the hydrolysis and subsequent stages[3] there is a possibility of interference from azobenzene itself. This has been avoided by using aqueous alkali for the hydrolysis, and a considerable increase in sensitivity has been achieved by reducing the *p*-nitrophenol to *p*-aminophenol with zinc dust and hydrochloric acid and converting to a blue indophenol compound with *o*-cresol and ammonia[4]. The latter reaction appears to be quite specific for *p*-nitrophenol in the presence of azobenzene. The relationship between the sensitivity of three methods of analysis using a Unicam SP350 D.G.Spectrophotometer with 1 inch cylindrical cells is shown by the calibration lines in fig. 1.

The method as developed and used so far has been tested on benzene solutions of parathion containing a ten-fold excess of azobenzene and on benzene solutions of parathion alone; on benzene extracts of cucumber foliage containing parathion and a ten-fold excess of azobenzene and on benzene extracts of cucumbers, tomatoes and tomato foliage containing parathion only.

The percentage recoveries obtained in all these experiments agreed satisfactorily although reflecting the cumulative effect of losses which occur at the various stages in the analysis (Table I).

It is hoped that a fuller account of this and related work may be given elsewhere.

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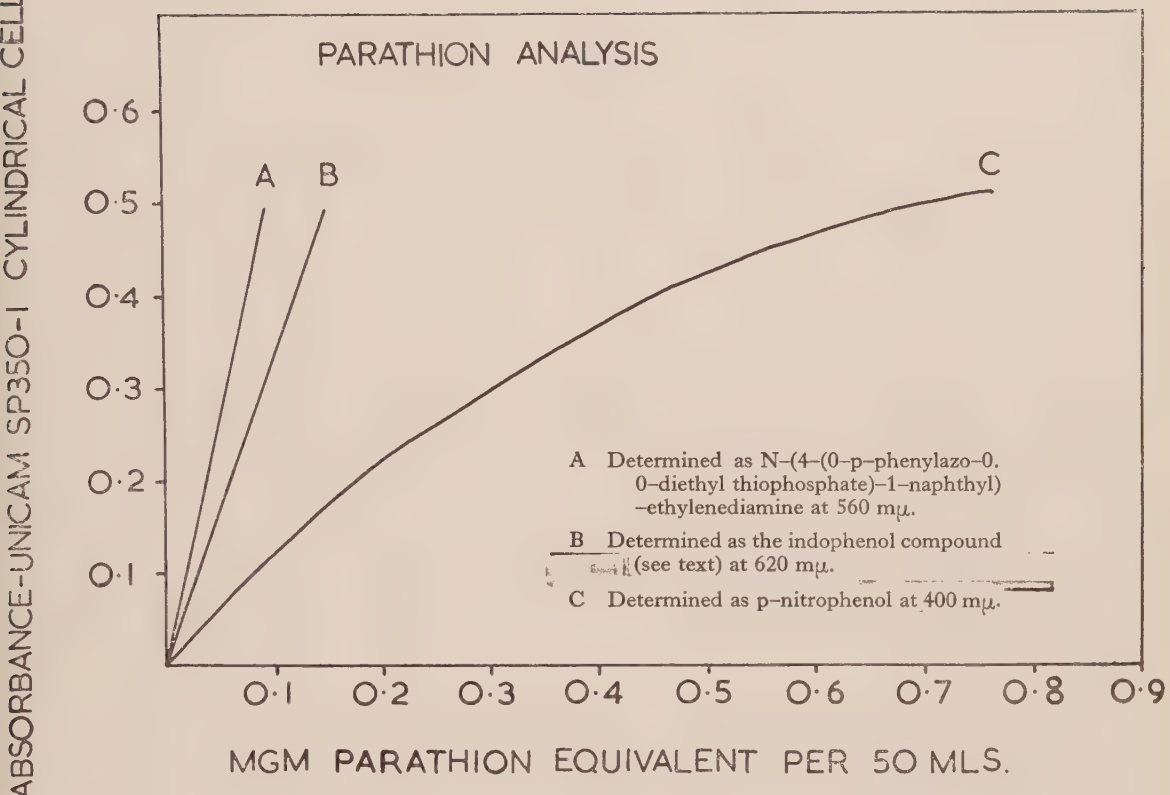

FIG. 1. Relative sensitivities of methods for the determination of parathion

TABLE I

Substrate	TAKEN		FOUND Parathion μ gm.	FOUND Parathion %
	Parathion μ gm.	Azobenzene mgm.		
10 mls. Benzene	24.2	0.226	21.5	89
	48.3	0.452	41.5	86
	72.5	0.678	56.5	78
	96.6	0.904	79.8	83
	120.8	1.130	100.5	83
	145.0	1.356	119.5	82
	169.1	1.582	138.5	82
10 mls. Benzene	24.2	—	18.2	75
	48.3	—	37.8	78
	72.5	—	54.0	75
	96.6	—	82.2	85
	120.8	—	96.0	80
	145.0	—	117.2	81
	169.1	—	144.0	85
10 mls. Cucumber Leaf extract (Benzene) equivalent to 20 gm. fresh leaves	24.2	0.226	22.0	91
	48.3	0.452	40.2	83
	120.8	0.678	102.0	84
50 mls. Cucumber extract (Benzene) equivalent to 100 gm. fruit	24.2	—	19.9	82
	48.3	—	40.1	83
	96.6	—	83.0	86
	193.3	—	175.0	91
40 mls. Tomato extract (Benzene) equivalent to 100 gm. fruit	24.2	—	20.5	85
	48.3	—	39.9	83
	96.6	—	80.5	83
	193,3	—	167.0	86
67 mls. extract of tomato foliage (Benzene) equivalent to 40 gm. fresh leaves	24.2	—	22.0	92
	48.3	—	39.7	82
	96.6	—	75.5	78
	145.0	—	113.1	78
	193.3	—	154.3	80

6. Chemical Investigations

1. THE COMPOSITION OF TOMATO FRUIT

by

D. M. MASSEY AND G. W. WINSOR

In the Annual Report of the Cheshunt Research Station for 1954 a scheme for the analysis of expressed sap from tomato fruit was outlined, suitable for the examination of relatively large numbers of samples. A summary of data obtained from paired samples of normal and "blotchy" fruit of variety Potentate, obtained from 16 nurseries in the Lea Valley, was presented, the concentration of total solids, reducing sugars, acids and nitrogenous compounds being significantly higher in the sap of normal than of blotchy whole fruit. It was also shown that, in the sap expressed from the dissected walls of blotchy tomato fruit, the concentrations of these same constituents were in general higher in the red areas than in the yellow or yellow-green areas.

The objects of experimental work in 1955 were, firstly, to confirm these findings in a further growing season, secondly to relate the results to the normal sequence of changes occurring during fruit-ripening, and lastly to make a preliminary comparison between the fruit of different varieties of tomato in relation to the incidence of "blotchy ripening."

Full laboratory facilities were, unfortunately, not established until rather late in the year, and by the end of the cropping season it was evident that further work on these subjects would still be necessary. The results which follow are therefore of the nature of a progress report, full discussion of the results being deferred until a later Report. It must also be emphasized that the analytical work now in progress, although showing a number of interesting features, should be regarded as a starting point for subsequent detailed biochemical studies of individual constituents of tomato fruit and of the enzyme processes concerned.

Comparison of the variously coloured portions of the walls of blotchy tomato fruit

The outer walls of blotchy fruit at commercial picking stage were dissected and graded into three batches on the basis of colour, as referred to in the Report of 1954[1]. Analyses of the expressed sap are recorded in Table I.

TABLE I

Analyses of sap expressed from variously coloured portions of the walls of 'blotchy' fruit

	Sample A			Sample B		
	Red	Yellow	Green	Red	Yellow	Green
Sap solids, g./100 mls.	3.85	3.50	3.20	4.25	4.04	4.06
Reducing sugars, g./100 mls. ...	2.70	2.51	2.19	3.32	3.24	3.34
pH	4.43	4.52	4.61	4.41	4.39	4.47
Titratable acidity*	4.0	3.4	3.1	4.0	3.6	3.1
Nitrogen, g./100 mls.	0.062	0.054	0.052	0.053	0.044	0.040
Phosphate (P_2O_5), g./100 mls. ...	0.020	0.018	0.020	0.021	0.019	0.016
Conductivity, mhos $\times 10^{-3}$ ...	5.02	4.81	4.85	4.72	4.52	4.27

* mls. N/10 NaOH per 10 mls. sap

The data for the sap solids show a decrease from the red to the green areas of fruit wall in sample A, and for sample B are higher in the red than in the yellow or green areas. The sugar content of the sap similarly decreased from red to green for sample A, though not for sample B. The titratable

acidity of the sap decreased from the red to the green areas in both samples, with generally corresponding changes in pH. The nitrogen content of the sap decreased from the red to the green areas, as did the phosphate content of sample B. The highest electrical conductivities were found in sap from the red areas.

In general the results for 1955 support those previously reported,[1] the main exception being found in the conductivity data. The results for sample B are of particular interest in that, whereas the sugar content of the sap showed little variation with colour, with consequently smaller changes in total sap solids, the titratable acidity continued to show well-marked differences. Considered together with the results for normal and blotchy whole fruit in 1954, it would seem that the organic acids of tomato fruit merit more detailed examination in subsequent studies.

Changes in the composition of expressed sap of tomato fruit during ripening

As previously stated, studies of the changes occurring in ripening fruit were considered necessary for interpretation of the differences established between normal and blotchy whole fruit[1], as well as for the differences between the variously coloured portions of the walls of blotchy fruit.

Fruit of variety Potentate was picked and sorted into five grades on the basis of external colouring:—

Stage 1 Green fruit without any trace of yellow colouration, from trusses in which other fruit had already begun to ripen.

Stage 2 Colour predominantly green, but with some yellow or orange colour developed.

Stage 3 Colour yellow-orange.

Stage 4 Colour orange-red.

Stage 5 Full red colour.

Grading of tomato fruit on the basis of colour presented considerable difficulty, but no satisfactory alternative appeared to be available. Thus Janes[2] noted that "Tomato fruits do not ripen at the same rate, making it necessary to have some other criterion than age as a measure of their maturity." The same author published data for titratable acidity, soluble solids and pH in the juice of field-grown tomatoes, but the method of obtaining the juice differed from that used in the present investigations. It was not found practicable to define the ripening stages in terms of colour charts, since the colours do not develop uniformly over the whole fruit in the early stages; only the last two stages approximated to single uniform colours. The fruit selected were of regular shape, those showing vascular browning or any other obvious abnormality when cut being excluded. It must be added, however, that in general the crop showed a considerable proportion of blotchy fruit and, on occasions, a tendency for the fruit to retain a yellow-orange colour rather than to develop to the full red shade; the latter effect was possibly due to high prevailing temperatures. Whereas blotchy fruit can readily be rejected at the later stages of ripening, some uncertainty inevitably arises at the stage of first appearance of yellow and orange colouration.

In addition to samples of whole fruit at the five stages of ripeness referred to, samples of the walls of the fruit were also taken. The contents of the locules, including free sap and seeds but excluding the placentae and internal fruit walls, were centrifuged and the free liquid filtered through glass wool for immediate examination by the methods previously described. In one instance the placenta and interlocular walls were also preserved for analysis.

The results obtained are summarized in Tables II-VIII; it should be emphasized that the colour grades given in the Tables refer to the external appearance of the fruit only, and not to the colours of the free sap or internal portions of the fruit.

TABLE II

Ripening Series. Whole fruit (31/5/55)

	Stage of ripening				
	1 Green	2 Green-Yellow	3 Yellow-Orange	4 Orange-Red	5 Red
Sap solids, g./100 mls.* ...	3.30	3.51	3.73	3.76	3.51
Reducing sugars, g./100 mls.*	2.19	2.42	2.56	2.63	2.45
Titratable acidity**	6.0	6.7	6.9	6.5	6.3
pH	4.27	4.12	4.13	4.19	4.26
Nitrogen, g./100 mls.	0.079	0.067	0.079	0.075	0.091
Phosphate (P_2O_5) g./100 mls.	0.033	0.028	0.029	0.033	0.045
Sap volume, mls./100 g. fruit	71.1	79.6	80.9	84.7	84.9
Conductivity, mhos $\times 10^{-3}$ ...	5.86	5.92	5.99	6.10	6.31
% dry matter in fruit	5.28	5.33	5.42	5.31	5.07

* Sap solids and reducing sugars measured in sap from a separate pressing of the same batch of fruit

** Mls. N/10 NaOH per 10 mls. of sap

TABLE III

Ripening Series. Fruit walls (6/6/55)

	Stage of Ripening				
	1 Green	2 Green-Yellow	3 Yellow-Orange	4 Orange-Red	5 Red
Sap solids, g./100 mls. ...	3.12	3.32	3.51	3.61	3.73
Reducing sugars, g./100 mls.	2.29	2.44	2.51	2.46	2.67
Titratable acidity	3.7	3.7	4.6	4.9	5.1
pH*	4.60	4.48	4.48	4.31	4.36
Nitrogen, g./100 mls.	0.054	0.050	0.052	0.065	0.074
Sap volume, mls./100 g. fruit	74.0	82.6	78.9	80.1	82.6
Conductivity*, mhos $\times 10^{-3}$	5.64	4.91	4.81	5.52	5.64

* pH and conductivity measured in sap from a separate pressing of the same batch of fruit

TABLE IV

Ripening Series. Free juices (6/6/55)

	Stage of ripening				
	1 Green	2 Green-Yellow	3 Yellow-Orange	4 Orange-Red	5 Red
Sap solids, g./100 mls. ...	3.89	4.21	4.35	4.38	4.28
Reducing sugars, g./100 mls.	1.89	2.42	2.48	2.42	2.47
Titratable acidity	11.8	11.0	11.1	10.7	9.2

TABLE V

Ripening Series. Whole fruit (15/6/55)

	Stage of ripening				
	1 Green	2 Green-Yellow	3 Yellow-Orange	4 Orange-Red	5 Red
Sap solids, g./100 mls. ...	3.50	3.69	3.84	4.11	4.02
Reducing sugars, g./100 mls.	2.27	2.56	2.59	2.72	2.69
Titratable acidity	6.6	5.3	5.7	6.3	6.0
pH	4.28	4.43	4.32	4.27	4.26
Nitrogen, g./100 mls.	0.074	0.063	0.059	0.068	0.079
Phosphate (P_2O_5), g./100 mls.	0.024	0.026	0.029	0.029	0.035
Sap volume, mls. (100 g. fruit)	72.1	82.6	84.3	84.3	84.0
Conductivity mhos $\times 10^{-3}$ ...	6.25	5.83	5.80	5.81	5.81
% dry matter in fruit	5.36	5.22	5.27	5.60	5.24

TABLE VI

Ripening Series. Fruit walls (15/6/55)

	Stage of ripening				
	1 Green	2 Green-Yellow	3 Yellow-Orange	4 Orange-Red	5 Red
Sap solids, g./100 mls. ...	3.13	3.31	3.59	3.67	4.01
Reducing sugars, g./100 mls.	2.38	2.57	2.71	2.81	3.09
Titratable acidity	3.8	3.5	4.7	4.7	5.4
pH	4.58	4.58	4.35	4.35	4.29
Nitrogen, g./100 mls.	0.049	0.040	0.052	0.054	0.074
Sap volume, mls./100 g. fruit	72.0	78.4	81.9	81.0	83.6
Conductivity, mhos $\times 10^{-3}$ ...	5.35	5.23	4.91	5.38	5.65

TABLE VII

Ripening series. Placentae and internal fruit walls (15/6/55)

	Stage of ripening				
	1 Green	2 Green-Yellow	3 Yellow-Orange	4 Orange-Red	5 Red
Sap solids, g./100 mls. ...	3.61	3.93	4.92	4.07	4.0
Reducing sugars, g./100 mls.	2.69	3.28	3.10	3.21	3.17
Titratable acidity	5.9	4.8	5.3	5.5	5.6
pH	4.45	4.47	4.40	4.38	4.34
Nitrogen, g./100 mls.	0.089	0.062	0.062	0.067	0.078
Sap volume, mls./100 g. fruit	76.8	78.2	81.3	82.4	82.5
Conductivity, mhos $\times 10^{-3}$ ...	6.31	5.33	5.47	5.47	5.49
% dry matter in fruit	5.49	5.56	5.88	5.58	5.91

TABLE VIII

Ripening Series. Free juices (15/6/55)

	Stage of ripening				
	1 Green	2 Green-Yellow	3 Yellow-Orange	4 Orange-Red	5 Red
Sap solids, g./100 mls. ...	3.91	3.98	4.11	4.05	4.23
Reducing sugars, g./100 mls.	2.02	2.43	2.41	2.46	2.57
Titratable acidity	12.1	9.3	10.5	9.0	9.2
Nitrogen, g./100 mls.	0.097	0.086	0.085	0.088	0.099

In general the concentration of sap solids increased with degree of ripeness from green to red for all parts of the fruit examined; data for the whole fruit do, however, show a slight fall in content of sap solids from the orange-red to the red grades, as also did the results for free juices in one instance (Table IV). The latter effect may be associated with over-ripeness. The content of reducing sugars in the sap in general also increased as ripening proceeded. In most series the most marked changes in sugar content occurred during the development of the first yellow colouration in the fruit walls, and the placentae and associated tissue (Table VII) showed a maximum value at this early stage. The sugar content of sap from both series of whole fruit again decreased between the fourth and fifth stages of ripeness, as previously noted for sap solids.

The data for titratable acidity of the sap samples during 1955 presents a more complex picture. Thus the acidity of the fruit walls increased from the yellow-green grade (stage 2) to full ripeness, the results for the two series being very similar throughout. The free sap, however, showed its highest acidity in the green fruit for both series; the data of Table IV show a fairly steady decline in acidity with degree of ripeness, while those of Table VIII fluctuate considerably before reaching the lowest values at the orange-red and red (fourth and fifth) stages. With the acidity of the walls increasing and that of the free sap decreasing with ripeness, the results for the whole fruit may be expected to show rather less variation throughout. No consistent trend can, indeed, be deduced from the data for the two series of whole fruit given in Tables II and V.

The nitrogen content of the sap in each case decreased from the green stage to either the second or third stages of ripeness, and subsequently increased. With the exception of the single set of data for placentae and internal walls in Table VII, the highest nitrogen content in each series of ripening stages was found in the fully ripe fruit.

Only two sets of data for phosphate are recorded in the Tables. In Table V the phosphate content of the sap rises progressively from green to red, whilst in Table II the results follow a pattern similar to that already described for nitrogenous compounds, decreasing during the first development of colour and rising subsequently to a relatively high value when fully ripe.

The volume of the sap expressed per unit weight of fresh fruit was, in general, somewhat lower for the green fruit than at all subsequent stages, the results for the later stages remaining reasonably constant at about 80 mls. or more per 100 g. of fruit. The higher yields of sap in these experiments as compared with those previously reported[1] are almost certainly due to improved facilities for freezing the fruit samples.

Discussion of results obtained with fruit of different stages of ripeness

The results of Tables II-VIII show quite consistent trends in the content of sap solids and sugars in the sap during ripening, these increasing in the walls, free juices and whole fruit. In contrast, however, the results for titratable acidity during 1955 show opposing trends in the walls and in the free sap, whilst no consistent trend is apparent for the whole fruit. At the time of writing this report

it is, furthermore, known that the acidity of the fruit walls sometimes decreases rather than increases during ripening from the stage of the first yellow colouration, thus showing a similar trend in both fruit walls and free juices. There is, indeed, considerable evidence to suggest that ripening processes in the walls and in the locular contents do not always bear a constant relationship one to the other. Thus, in the fruit of variety Potentate used in these experiments, the mucilaginous material surrounding the seeds in general changed both in colour and in physical condition before any very marked change in colour or firmness of the fruit wall was readily apparent. Fruit having red or orange-red walls of normal appearance, however, not infrequently showed immature locular contents when cut open.

Relation of the results previously obtained from comparison of normal and blotchy fruit to the general sequence of changes during ripening will be deferred until the results for another season are available and the trends in acidity clarified.

The composition of sap expressed from fruit of different varieties

In view of the obvious tendency for fruit of variety Potentate to show a high incidence of blotchy ripening, almost all the experimental work on this disorder during 1954 was confined to the one variety. It would clearly be of considerable interest if any differences in composition could be established between fruit of Potentate or related varieties and the fruit of other varieties less susceptible to the disorder.

During 1955 fruit was available from single plots (60-70 plants) of 10 varieties in house F.1; eight of these varieties were examined in July (4/7/55),and all 10 varieties in August (8/8/55) and September (23/9/55). The samples used consisted of good quality fruit, graded as "Pink and White." Monthly crop records for these varieties are summarized at the beginning of this Report. The plants cropped fairly heavily, nine out of the 10 yielding 10-12lbs. per plant. In general the crop reached its maximum in July, and declined markedly in September; Potentate and E.S.5 gave the heaviest early crop. The percentage of blotchy fruit is shown in Table IX, based on records supplied by the crop recorders. During June the highest percentage of blotchy fruit was recorded from Potentate, followed by the Wheatley variety and E.S.5. For July the percentage of blotchy fruit from Potentate was less than a third of the June figure, but remained relatively high, being equalled only by Delicious. By August most varieties showed a relatively low percentage of blotchy fruit, though the figure for Potentate remained similar to that of July.

TABLE IX

The percentage of blotchy fruit from 10 varieties during June, July, and August, and also for the whole season (1955)

	% Blotchy fruit			
	June	July	August	Total
Downes Seedling ...	8.6	3.0	2.1	3.6
Delicious	4.5	13.6	6.8	7.7
E.S.1	7.4	1.5	0.8	2.5
Wheatley	18.1	0.5	—	3.4
Potentate	44.6	13.1	13.7	20.7
E.S.5	11.2	0.9	1.9	3.7
Radio	1.8	9.0	6.0	5.5
Potential	5.2	7.8	1.5	4.0
Ailsa Craig	2.9	1.0	1.6	1.5
L.M.R.I.	1.1	5.0	1.0	2.0

The results obtained on analysis of the expressed sap of whole fruit are summarized in Table X, together with the percentage dry matter content of the fruit. All values are the means of duplicate determinations.

TABLE X

Analytical results for the expressed sap from fruit of 10 varieties of tomato, together with the percentage dry matter in the fruit. (House F.1., 1955)

		Downes* Seedling	Delicious*	E.S.1	Wheatley	Potentate	E.S.5	Radio	Potential	Ailsa Craig	L.M.R.1.
Titratable acidity ... ... (mls. N/10 NaOH per 10 mls. of sap)	July	—	—	8.6	8.6	6.8	9.2	10.4	8.1	9.3	11.1
	August	9.3	11.6	7.6	8.2	6.3	7.8	8.7	6.5	7.7	9.5
	September	8.3	7.6	6.6	6.8	7.1	7.4	7.8	6.2	7.1	8.4
Sap solids, g./100 mls. ...	July	—	—	4.33	4.12	4.12	4.55	4.39	4.33	4.25	4.55
	August	4.77	5.35	4.41	4.53	4.28	4.24	4.46	4.66	4.28	5.01
	September	3.92	3.93	4.15	4.26	4.00	3.94	3.83	3.98	3.72	4.43
Reducing sugars, g./100 mls.	July	—	—	2.91	2.83	2.94	3.01	2.77	3.02	2.74	2.88
	August	2.68	3.34	2.84	2.80	3.18	2.91	2.77	3.18	2.80	2.90
	September	2.67	2.96	3.08	3.06	2.81	2.82	2.81	2.99	2.57	3.05
Nitrogen, mg./100 mls. ...	July	—	—	87.6	84.5	66.7	92.5	91.5	87.6	93.2	95.6
	August	87.2	79.9	68.5	82.4	75.0	88.7	61.8	64.1	73.6	77.3
	September	—	—	—	—	—	—	—	—	—	—
Conductivity (mhos $\times 10^{-3}$)	July	—	—	6.73	6.26	5.99	6.91	6.86	6.30	6.79	6.79
	August	6.91	6.94	5.97	6.25	5.49	6.26	5.97	5.47	5.65	5.64
	September	5.49	4.59	4.23	5.10	5.17	5.22	4.97	5.02	5.47	4.83
% dry matter in fruit ...	July	—	—	5.75	5.32	5.58	5.86	5.68	5.74	5.59	5.95
	August	5.99	7.56	5.75	5.54	5.77	5.22	5.72	5.66	5.57	6.12
	September	5.62	5.65	5.55	5.86	5.66	5.67	5.48	5.65	5.55	6.33

* Not sampled in July

The results for the July sampling show several interesting features. Thus the titratable acidity showed a considerable range of values, that for Potentate being relatively low and those for L.M.R.1 and Radio particularly high. The lowest values for total sap solids in July were found for Potentate and the Wheatley variety, and the highest for L.M.R.1 and E.S.5. The lowest sugar content was shown by Ailsa Craig and Radio, the highest by Potential and E.S.5. By far the lowest nitrogen content was found in the sap of Potentate, the highest in that of L.M.R.1, Ailsa Craig and E.S.5. Sap from variety Potentate showed the lowest electrical conductivity. The Wheatley variety gave the lowest percentage dry matter in the fruit and L.M.R.1, the highest.

At the sampling in August, fruit of Downes Seedling and Delicious were examined for the first time; on this occasion Delicious gave the highest values for acidity, sap solids and dry matter content of all the varieties during the season. At this time of sampling the fruit of variety Potentate available was found to be markedly less ripe than that of the other varieites, and had to be replaced by another sample from the next picking, thus unfortunately reducing the value of comparisons with this variety during August. Potentate and Potential gave the lowest acidities among all the 10 varieties, and of the eight varieties previously sampled in July, L.M.R.1 again gave the highest value. The highest values for sap solids were found in Delicious and L.M.R.1, for sugars in Delicious, Potential and Potentate, and for percentage dry matter in the fruit in Delicious, L.M.R.1 and Downes Seedling. The nitrogen content of the expressed sap of nearly all varieties was markedly lower in August than in July, with the exception of Potentate.

In September the results for titratable acidity show far less variation between varieties, no outstandingly high values being recorded: the lowest value was that for Potential. In general the results for Potentate at this stage occupy intermediate positions in the data for acidity, sugars, sap solids and percentage dry matter.

With regard to seasonal trends the titratable acidities show a marked decline as the season progressed, with the exception of Potentate which was already low at the first date of sampling. The electrical conductivities of the sap samples also decreased markedly from the July to the September samplings. With one exception the values for sap solids were lowest in September, but consistent trends are not readily apparent among the data for sugars in the sap or for percentage dry matter in the whole fruit.

Several points of particular interest may be noted amongst the data of Table X. Thus the low acidity of the expressed sap of Potentate fruit, particularly at the first date of sampling when varieties such as L.M.R.1. and Radio showed relatively high values, is of interest. The range of values for titratable acidity at this stage merits further attention, and detailed examination of the various acids present is desirable. Attention may also be drawn to the results for L.M.R.1. Thus of the eight varieties sampled on all three occasions L.M.R.1 showed the highest acidity each time, and was only surpassed in one instance by Delicious (when first sampled in August). The same conclusion applies to the percentage dry matter in the fruit and to the results for sap solids, except that in the latter case L.M.R.1 and E.S.5 jointly showed the highest value of the group for July. The highest nitrogen content of the sap recorded in the whole Table was that for L.M.R.1 in July. Variety L.M.R.1 furthermore showed the highest total crop per plant, of which only 2.0% was graded as "blotchy"; it must, however, be added that only single plots of each variety were available, and that L.M.R.1 occupied a position at the South end of the house. Fruit from replicated plots will be necessary for any subsequent studies of this nature.

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2. UREA-FORMALDEHYDE COMPOUNDS AS NITROGENOUS FERTILIZERS

by

M. I. E. LONG and G. W. WINSOR

In earlier experiments on the decomposition of certain urea-formaldehyde samples in a wide range of soils, as described in the Annual Report for 1954[1] and elsewhere[2], it was shown that soil pH markedly influenced the rates of mineralization of nitrogen. At the same time it was noted that the solubility of urea-formaldehyde samples in buffer solutions also increased with the degree of acidity. Data to illustrate the latter relationship are presented in Table I; in this experiment 0.2g. samples of urea-formaldehyde plastic waste ("flash"), in finely ground condition, were immersed in a series of buffer solutions having eight pH values from 4 to 8. After periods of two and seven days the suspensions were filtered, and soluble nitrogen determined in the filtrates. The results show a very marked increase in soluble nitrogen with increasing acidity.

TABLE I

Soluble nitrogen, expressed as a percentage of the total nitrogen content of the sample, on incubation of urea-formaldehyde plastic waste with buffer solutions of pH 4–8

	% soluble nitrogen	
pH of solution	After 2 days	After 7 days
8.0	7.0	9.1
7.0	8.1	10.4
6.5	8.7	13.1
6.0	15.3	18.3
5.5	18.7	26.1
5.0	26.6	39.9
4.5	34.0	45.0
4.0	37.9	50.5

In view of these results both in soils and buffer solutions having various pH values, a further series of experiments was undertaken in which a wide range of urea-formaldehyde samples was studied in two soils having initial pH values of 5.3 (soil A) and 7.5 (soil B), and also in buffer solutions of the same pH values. The objects of this investigation were firstly to compare decomposition of the various urea-formaldehyde samples in the acid and calcareous soils, secondly to compare the solubility of the samples in buffer solutions having pH values similar to the two soils, and finally to assess the value of the solubility tests as a guide to the behaviour of the urea-formaldehyde samples in the soil.

The urea-formaldehyde materials tested were selected from the wide range of samples available from previous studies; their nitrogen content was re-determined immediately prior to the present experiments in order to allow for possible changes in moisture content during storage. The samples selected include some prepared under acid conditions at various urea-formaldehyde (U/F) ratios of not less than one, comparable samples prepared by reaction under alkaline conditions followed by a brief acid treatment, and a range of materials prepared at an initial U/F ratio of 0.5. Brief details of the various preparations are included in Table II, together with references to earlier Reports. The preparation of samples 135a-h was identical throughout except in the conditions of drying as specified in Table III.

TABLE II

Description of urea-formaldehyde samples used in the tests

Sample No.	U/F ratio of reactants	Conditions of preparation	Reference	% Total Nitrogen	Free urea-* Nitrogen	% Total Formaldehyde	U/F ratio** of product
17	1.00	Reaction at pH 3.5 for 20 minutes at 90°C.	Ann. Rep. 1951.p.57	34.3	0.3	34.2	1.07
18	1.20	,, ,, ,,	,, ,,	37.2	4.1	31.4	1.22
19	1.40	,, ,, ,,	,, ,,	37.5	10.6	27.9	1.29
20	1.60	,, ,, ,,	,, ,,	39.3	15.4	26.0	1.37
21	1.80	,, ,, ,,	,, ,,	40.2	20.5	23.4	1.47
22	2.00	,, ,, ,,	,, ,,	40.2	27.8	21.3	1.46
46	1.20	Reaction at pH 3.5 for 24 hours at 25°C.	Ann. Rep.	35.7	0.1	31.4	1.22
47	1.60	,, ,, ,,	1951, p.65	37.4	3.1	30.1	1.29
80a	1.60	Alkaline reaction for 1 hour followed by acid reaction at pH 4.5 for 5 minutes	Ann.Rep. 1954.p.43 and 45	38.6	15.6	24.3	1.44
83a	1.50	,, ,, ,,	,, ,,	38.3	11.1	25.7	1.42
86a	1.40	,, ,, ,,	,, ,,	37.8	9.0	27.1	1.36
89a	1.30	,, ,, ,,	,, ,,	36.9	7.2	28.5	1.26
92a	1.20	,, ,, ,,	,, ,,	36.4	4.9	29.8	1.24
95a	1.00	,, ,, ,,	,, ,,	34.1	1.6	34.4	1.05
117a	1.50	As for 80–95a, but with acetic acid.	—	38.4	15.7	25.6	1.36
120a	1.60	pH 4.5, 100°C. Formaldehyde added in 2 Portions.	—	38.2	14.4	27.1	1.29
135a	0.50	Refluxed for 1 hour at pH 5.5; conditions of drying as specified in Table III.	*c.f.*Ann. Rep. 1954 p.47	23.6	0	43.5	0.58
135b	0.50	,, ,, ,,	,, ,,	24.7	0	42.1	0.63
135c	0.50	,, ,, ,,	,, ,,	22.5	0	43.9	0.55
135d	0.50	,, ,, ,,	,, ,,	23.1	0	43.2	0.57
135e	0.50	,, ,, ,,	,, ,,	27.0	0	50.8	0.57
135f	0.50	,, ,, ,,	,, ,,	28.3	0	51.5	0.59
135g	0.50	,, ,, ,,	,, ,,	26.3	0	49.5	0.57
135h	0.50	,, ,, ,,	,, ,,	26.3	0	49.6	0.57

* As % of total nitrogen

** Corrected for free urea where present

TABLE III

Conditions of drying for samples 135 a–h

	a	b	c	d	e	f	g	h
Temperature (°C) ...	110	110	65	65	110	110	65	65
Time (Hours) ...	2	24	24	72	2	24	72	168
Added peat ...	+	+	+	+	—	—	—	—

Experimental methods

The urea-formaldehyde samples were mixed with 700 g. of moist soil at concentrations equivalent to 300 p.p.m. of added nitrogen calculated on the basis of oven-dry soil. The soil samples were incubated at a temperature of 23.5°C., and the moisture content maintained at 85% of the soil moisture equivalent as determined by the method of Bouyoucos[3]. Samples were removed for the determination of total inorganic nitrogen and pH after periods of 3 and 12 weeks.

Further samples (0.2 g.) of the 24 urea-formaldehyde materials were immersed in 100 mls. of two buffer solutions having pH values of 5.3 and 7.5, and incubated at 23.5°C. After one week the suspensions were filtered, and soluble nitrogen determined. The filtrates from the buffer solution of pH 7.5 were also analysed for total formaldehyde in solution.

Free formaldehyde in the buffer solutions was determined by the method of Donally[4] as modified by de Jonge[5]. Total formaldehyde, including free formaldehyde and combined formaldehyde in both methylol and methylene groupings, was determined as follows:—

An aliquot of the solution was distilled with phosphoric acid (25 mls.) and water (40 mls.), 300 mls. of distillate being collected in a receiver containing sodium sulphite (2 mls. of 2N solution). Before the end of the distillation the pH of the distillate was adjusted to 8.5 to ensure completion of the reaction between sulphite and formaldehyde. The distillate was then acidified with acetic acid and the determination completed as for free formaldehyde[5].

Results

The percentage mineralization of the nitrogen of the 24 urea-formaldehyde samples in soils A and B after periods of 3 and 12 weeks is shown in Table IV.

As previously found[1], mineralization of the nitrogen of the acid-condensed samples having initial U/F ratios of not less than 1 (samples 17-22; 80a-95a) increased with increasing U/F ratio. Without exception, decomposition of each urea-formaldehyde sample was more rapid in the acid soil A than in the calcareous soil B, as shown by the results for both 3– and 12–week periods of incubation. Values for the percentage mineralization of added nitrogen in soil A (pH 5.3), less that in soil B (pH 7.5), have been included in Table IV.

As shown in an earlier Report[1], decomposition of the urea-formaldehyde samples influenced the pH of the soil. Thus soil A, having an initial pH of 5.3, gave values of 4.2–5.0 after incubation with urea-formaldehyde samples for 12 weeks. In the calcareous soil the pH showed little change on incubation for three weeks, but decreased subsequently despite an initial carbonate content of 0.88% (calculated as calcium carbonate). This latter result was unexpected, since the amount of carbonate present was far in excess of that theoretically required to neutralise the acidity arising from nitrification, and it thus seems that equilibrium was not attained in the soil.

The results obtained after incubation of the 24 urea-formaldehyde samples for one week in buffer solutions of pH 5.3 and 7.5 are shown in Table V.

For the acid-condensed samples having initial U/F ratios greater than 1 (samples 17–22, 80a–95a) the percentage of soluble nitrogen at both pH values, and of formaldehyde in solution at pH 7.5, increased with increasing U/F ratio, as did the percentage mineralization of these two groups of

TABLE IV

Mineralization of the nitrogen of 24 samples of urea-formaldehyde in soil A (initial pH 5.3) and soil B (initial pH 7.5)

	% nitrogen mineralized					
	On incubation for 3 weeks			On incubation for 12 weeks		
Sample No.	Soil A	Soil B	A–B	Soil A	Soil B	A–B
17	4.6	1.6	3.0	4.6	0	4.6
18	17.8	5.9	11.9	28.2	2.4	25.8
19	28.4	15.5	12.9	51.9	21.6	30.3
20	46.1	29.4	16.7	68.1	40.3	27.8
21	58.9	41.0	17.9	79.3	49.5	29.8
22	74.7	51.4	23.3	88.4	65.4	23.0
46	5.9	2.5	3.4	19.4	13.2	6.2
47	24.5	5.9	18.6	57.2	36.3	20.9
80a	76.7	43.1	33.6	86.4	61.5	24.9
83a	69.4	35.6	33.8	83.7	52.3	31.4
86a	61.7	33.9	27.8	77.9	47.7	30.2
89a	58.0	29.9	28.1	74.0	42.5	31.5
92a	44.0	21.4	22.6	52.3	29.7	22.6
95a	33.5	12.9	20.6	47.6	18.0	29.6
117a	63.3	35.4	27.9	73.2	48.4	24.8
120a	64.0	36.3	27.7	71.4	48.4	23.0
135a	33.8	8.3	25.5	68.6	16.7	51.9
135b	26.8	6.5	20.3	65.6	13.6	52.0
135c	52.0	19.0	33.0	82.3	25.0	57.3
135d	50.9	19.0	31.9	79.1	24.4	54.7
135e	42.7	8.8	33.9	67.8	16.7	51.1
135f	37.0	7.5	29.5	59.4	13.7	45.7
135g	46.9	11.4	35.5	79.9	22.9	57.0
135h	45.6	10.9	34.7	78.9	20.1	58.8

TABLE V

*Soluble nitrogen in buffer solutions of pH 5.3 and 7.5, and soluble formaldehyde at pH 7.5, on incubation of 24 urea-formaldehyde samples for 1 week**

Sample No.	U/F ratio of reactants	Soluble nitrogen		Soluble formaldehyde pH 7.5
		pH 5.3	pH 7.5	
17	1.00	6.4	1.3	0.4
18	1.20	13.4	9.3	3.9
19	1.40	24.7	20.3	7.0
20	1.60	46.4	44.1	24.4
21	1.80	60.3	51.7	29.0
22	2.00	76.6	66.7	51.4
46	1.20	2.8	3.6	0.3
47	1.60	15.4	11.6	5.4
80a	1.60	83.2	80.1	70.0
83a	1.50	72.5	71.1	61.1
86a	1.40	64.8	62.8	52.9
89a	1.30	66.6	58.8	48.9
92a	1.20	50.8	50.9	45.1
95a	1.00	37.4	37.4	34.0
117a	1.50	65.1	66.1	52.5
120a	1.60	64.9	66.2	55.0
135a	0.50	67.4	42.9	42.6
135b	0.50	52.3	25.3	31.9
135c	0.50	87.2	84.9	90.3
135d	0.50	84.6	82.3	80.1
135e	0.50	60.3	28.9	39.9
135f	0.50	51.0	18.0	29.4
135g	0.50	91.6	76.6	81.7
135h	0.50	84.5	63.2	80.2

* Expressed as a percentage of the total nitrogen or formaldehyde content of the sample

samples in both soils (Table IV). In general the amounts of soluble nitrogen found in the solutions at pH 5.3 were greater than at pH 7.5, though certain exceptions may be noted. The greatest effect of pH on the amounts of soluble nitrogen present is found among the samples prepared at an initial U/F ratio of 0.5 (135a–h); the increased solubility of the nitrogenous compounds in the acid buffer solution as compared with the buffer solution of pH 7.5 is, however, statistically significant whether or not samples 135a–h are included.

Correlations between the results of the various tests

In calculating the correlation coefficients of Table VI the percentage mineralization of nitrogen in soils of initial pH 5.3 and 7.5 has been related to the soluble nitrogen present in buffer solutions having the same pH values. The data for total soluble formaldehyde are, however, based on the results obtained with buffer solutions of pH 7.5 only. The soluble formaldehyde found in the buffer solution tests was almost entirely present in combined form; in relating the formaldehyde determinations to mineralization of nitrogen in the soil the free urea present in the samples, which is readily decomposed in the soil, has been deducted from the results of the soil tests, the data thus referring to urea-formaldehyde compounds alone.

The correlation coefficients in Table VI relating decomposition of the 24 urea-formaldehyde samples in the two soils to the soluble nitrogen found in the corresponding buffer solutions are highly significant throughout. Graphs of the data, however, show a tendency for the samples to fall into two groups, namely those with U/F ratios greater than and less than 1 (samples 17–120 and 135a–h respectively); in general the samples prepared at an initial U/F ratio of 0.5 showed a higher solubility in the buffer solutions in relation to their rates of decomposition in the soil than was the case for samples of higher U/F ratio. For this reason correlation coefficients excluding samples 135a–h are in some cases higher than those calculated for all 24 samples.

The correlations between total soluble formaldehyde in the buffer solutions of pH 7.5 and the percentage mineralization of nitrogen in both soils were also highly significant throughout, though some differences in the behaviour of samples prepared at U/F ratios greater than and less than 1 were again noted.

Discussion of results

In previous experiments described in the Annual Report for 1954[1], in which decomposition of two samples of urea-formaldehyde was studied in 20 soils having initial pH values ranging from 3.9 to 7.8, it was shown that mineralization of nitrogen increased with increasing soil acidity. Both of the samples then used, one of which consisted of commercial plastic waste, had U/F ratios of less than 1, and thus differed from the typical urea-formaldehyde materials now available as slow-acting fertilizers in America. The present experiments, in which 24 samples prepared under widely differing conditions are compared in an acid and a calcareous soil, confirm the previous finding that decomposition of urea-formaldehyde compounds is more rapid in an acid soil than in one of higher pH. Thus the results in Table IV in every case show greater mineralization of nitrogen in the acid soil. It may be noted that decomposition of samples 135a–h, prepared at an initial U/F ratio of 0.5 by methods similar to sample A in the previous experiments (Ann. Rep. 1954, p.48, Table VII), was more markedly influenced by soil pH than was the case for the other 16 samples; increased mineralization of the nitrogen of all samples prepared at U/F ratios greater than 1 was, however, clearly demonstrated in the acid soil.

The highly significant correlation coefficients in Table VI indicate that either the soluble nitrogen or soluble formaldehyde found in the buffer solubility tests may be used as a reasonably satisfactory guide to the decomposition of urea-formaldehyde samples in the soil. The amounts of soluble nitrogen found in buffer solution of pH 5.3 were, without exception, higher than at pH 7.5 for samples 135a–h; the results for samples 17–120, prepared at initial U/F ratios greater than 1, were

TABLE VI

Correlation coefficients relating mineralization of the nitrogen of some urea-formaldehyde samples in soil and the soluble nitrogen and formaldehyde present on incubation of the samples with buffer solutions

Determination in buffer solutions	Number of samples	Soil A (pH 5.3)		Soil B (pH 7.5)	
		3 weeks	12 weeks	3 weeks	12 weeks
Soluble nitrogen†	24	0.81***	0.90***	0.68***	0.66***
,, ,, excluding samples 135 a–h	16	0.99***	0.92***	0.93***	0.90***
,, ,, samples 135 a–h only	8	0.83**	0.97***	0.87**	0.98***
Total soluble formaldehyde (pH 7.5)	24	0.89***	0.85***	0.70***	0.59**
,, ,, ,, excluding samples 135 a–h	16	0.98***	0.83***	0.96***	0.85***
,, ,, ,, samples 135 a–h only ...	8	0.87**	0.97***	0.86**	0.98***

† Soluble nitrogen in buffer solutions of pH 5.3 and 7.5 correlated with results for soils of intial pH 5.3 and 7.5 respectively

** Significant at P = 0.01

*** Significant at P = 0.001

less consistent in this respect, though the increases in solubility of the nitrogenous compounds at pH 5.3 as compared with pH 7.5 are statistically significant. It is apparent that differences between the solubility of urea-formaldehyde samples in the buffer solutions of pH 5.3 and 7.5 are not closely related to the corresponding differences between their rates of decomposition in soils of similar initial pH.

The results in Table IV also confirm the previous finding[1] that urea-formaldehyde compounds prepared by reaction under alkaline conditions, followed by a brief period of acid treatment, are more readily decomposed in the soil than products prepared at similar initial U/F ratios under acid conditions alone. Data for samples 17–20 and 80a–95a on incubation for three weeks in soils A and B are summarized for comparison in Table VII.

TABLE VII

Comparison of the percentage mineralization of nitrogen from urea-formaldehyde samples prepared under acid conditions with those obtained by successive alkaline and acid reactions. The data shown are for a 3-week period of incubation in two soils

U/F ratio*	Soil pH 5.3		Soil pH 7.5	
	Acid reaction	2-stage reaction	Acid reaction	2-stage reaction
1.6	46.1	76.7	29.4	43.1
1.4	28.4	61.7	15.5	33.9
1.2	17.8	44.0	5.9	21.4
1.0	4.6	33.5	1.6	12.9

* Initial U/F ratio of reactants

SUMMARY

1. Laboratory trials with 24 samples of urea-formaldehyde materials without exception showed more rapid decomposition in an acid soil (initial pH 5.3) than in a calcareous soil (initial pH 7.5).
2. The experiments described, together with those previously reported for two samples of urea-formaldehyde in 20 soils of pH 3.9–7.8 (Ann. Rep. 1954, pp. 48–49), indicate that pH is an important factor in the decomposition of urea-formaldehyde compounds in the soil.
3. The rates of decomposition of urea-formaldehyde samples in a given soil are significantly correlated with their solubility in buffer solutions, as shown by determinations of either nitrogen or formaldehyde.

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3. STEAM STERILIZATION STUDIES

by

J. N. DAVIES

A. The effect of partial sterilization upon the manganese status of soils

Manganese occurs in the soil in different forms with widely varying solubilities. Therefore it is necessary to distinguish between total and available manganese. Total manganese is of secondary importance for plant growth. Of much more significance is the available or "active" manganese as it is called by Leeper[1,2]. This includes water-soluble and exchangeable divalent manganese and those forms of manganic oxide which are easily reduced by hydroquinone at pH 7. This report deals with the effect of steam sterilization on the available manganese in various glasshouse and garden soils.

Experimental methods and materials

Three soils were used extensively in this investigation namely, a glasshouse soil (pH *ca.* 8), a garden soil (pH *ca.* 6), and a maiden loam from under turf (pH *ca.* 4). The total manganese contents of these soils were 674, 322 and 518 p.p.m. respectively. A number of other soils were used to a lesser extent; details of these are given later.

Prior to steaming the moisture content of the soils was adjusted to a value corresponding to 90% of the moisture equivalent as determined in a soil centrifuge. The soils were partially sterilized in an autoclave for 20 minutes at zero pressure, and subsequently incubated at 23.5°C.

For the determination of water-soluble and exchangeable manganese, moist soil samples were shaken for 30 minutes with distilled water or neutral normal ammonium acetate respectively, followed by filtration under gentle suction. A soil: extractant ratio of 1:10 was employed. This procedure is essentially that of Sherman *et al*[3] except that separate samples were taken for each extracting solution. Easily reducible manganese was extracted with normal ammonium acetate (pH 7) containing hydroxylamine hydrochloride (0.2%) as suggested by Dion, Mann and Heintze[4]. The substitution of hydroxylamine hydrochloride for hydroquinone as the reducing agent avoids the troublesome destruction of the hydroquinone prior to the colorimetric manganese determination. Subsequent treatment of the filtrates followed the procedure described by Hurwitz[5].

Manganese estimations were carried out using the periodate method of Willard and Greathouse[6] in the presence of nitric and phosphoric acids. The colour intensities were measured with a "Spekker" absorptiometer using 4 cm. cells and Ilford Spectrum Green filters.

Total manganese in the soils was determined by the wet combustion procedure described by Wain[7].

pH determinations were carried out using the glass electrode, a soil: water ratio of 1: 2.5 being employed. Total nitrogen was estimated by the Kjeldahl procedure.

All results are expressed on an oven dry soil basis.

Results

Changes in water-soluble and exchangeable manganese after steaming are shown in Tables I, II and III for the glasshouse soil, garden soil and maiden loam respectively.

It will be seen that steaming brought about an immediate increase in water-soluble and exchangeable manganese in each of the three soils. In the alkaline glasshouse soil the increase was very small, and after incubation the levels fell again to values little different from those in the unsteamed soil. In the two acid soils, however, the immediate increase in the water-soluble and exchangeable manganese content was followed by a further increase during the first week or 10 days of incubation. Thereafter the levels remained substantially constant.

TABLE I

Glasshouse Soil

Time, days	Unsteamed			Steamed		
	p.p.m. Mn			p.p.m. Mn		
	Water soluble	Exchangeable	pH	Water soluble	Exchangeable	pH
0	0.5	0.4	8.04	1.3*	5.9*	8.04*
4	0.5	0.7	8.01	Trace	3.2	8.23
6	0.8	0.4	8.08	1.1	2.3	8.26
14	Trace	1.0	7.98	Trace	3.1	8.34
34	Trace	0.7	7.81	Trace	1.4	8.28

* Analyses made immediately after steaming

TABLE II

Garden Soil

Time, days	Unsteamed			Steamed		
	p.p.m. Mn			p.p.m. Mn		
	Water soluble	Exchangeable	pH	Water soluble	Exchangeable	pH
0	0.5	1.4	5.69	2.9*	15.3*	5.51*
2	Trace	1.3	5.64	1.5	22.6	5.64
7	,,	1.3	5.61	2.4	28.6	5.72
13	,,	1.9	5.60	2.0	24.4	5.76
23	,,	2.0	5.65	3.6	24.3	5.80
43	,,	1.3	5.67	3.5	23.6	5.78

* Analyses made immediately after steaming

TABLE III

Maiden Loam

Time, days	Unsteamed			Steamed		
	p.p.m. Mn			p.p.m. Mn		
	Water soluble	Exchangeable	pH	Water soluble	Exchangeable	pH
0	14.3	53.9	4.34	24.7*	106.3*	4.26*
2	15.0	63.2	4.30	30.5	109.9	4.39
4	17.8	82.8	4.41	26.3	126.0	4.48
7	14.7	75.6	4.44	26.4	131.1	4.52
11	15.9	73.9	4.40	23.0	144.1	4.66
17	9.2	77.5	4.48	16.2	138.7	4.71
25	15.0	81.6	4.46	21.7	144.0	4.64
80	20.2	77.9	4.44	22.1	143.7	4.60

*Analyses made immediately after steaming

At the time of steaming only 0.13% of the total manganese content of the unsteamed glasshouse soil was accounted for in water-soluble and exchangeable forms. Corresponding values for the garden soil and the maiden loam were 0.6 and 13.2% respectively. Immediately after steaming these values increased to 1.1% for the glasshouse soil, 5.7% for the garden soil and 25.3% for the maiden loam.

The effect of pH

The maiden loam was treated with lime at rates corresponding to 0.25, 0.5, 1.0 and 2.0% of the dry soil weight. The treated soils were then incubated and samples analysed at intervals for water-soluble and exchangeable manganese. At the same times other samples were partially sterilized, and the water-soluble and exchangeable manganese determined immediately after the soils had cooled. Water losses due to evaporation were made up periodically. The results are shown in Table IV.

TABLE IV

Amount of Lime Added	Unsteamed			Steamed		
	p.p.m. Mn		pH	p.p.m. Mn		pH
	Water soluble	Exchangeable		Water soluble	Exchangeable	
7 days after liming						
None	19.6	69.4	4.40	26.5	96.3	4.28
0.25%	12.7	53.9	6.98	12.8	64.4	6.69
0.5%	5.6	43.2	7.22	7.9	49.6	7.21
1.0%	4.8	41.7	7.63	5.0	43.6	7.46
2.0%	2.6	29.4	7.88	4.6	38.9	7.71
21 days after liming						
None	24.4	66.7	4.36	27.8	83.4	4.32
0.25%	6.7	26.0	6.37	10.1	41.5	6.27
0.5%	2.4	18.3	7.46	2.8	21.4	7.20
1.0%	1.3	16.1	7.84	2.5	21.5	7.56
2.0%	0.8	17.8	7.90	0.8	21.3	7.75
137 days after liming						
None	18.1	38.4	4.43	19.0	84.7	4.42
0.25%	2.6	7.5	5.66	3.2	10.4	5.77
0.5%	1.6	2.5	7.25	2.6	1.5	7.21
1.0%	1.4	0.4	7.65	2.6	1.5	7.58
2.0%	Trace	1.5	7.81	Trace	3.1	7.68

In the unsteamed soils, the addition of increasing amounts of lime resulted in a progressive decrease in the levels of water-soluble and exchangeable manganese. After steaming only small increases in water-soluble and exchangeable manganese were observed in the limed soils. In general, the longer the soil was stored in the presence of lime before steaming, the smaller was the increase in water-soluble and exchangeable manganese after steaming.

Some relationships between the increase in water-soluble and exchangeable manganese after steaming and other soil properties.

A group of 18 soils including glasshouse soils, maiden loams and field and garden soils was steamed and when cold analysed for water-soluble, exchangeable and easily reducible manganese. Detailed results for the various forms of manganese in the soils, both steamed and unsteamed, together with data for pH, total manganese and total soil nitrogen are given in Table V.

In the unsteamed soils with pH values greater than about 5.5 there were only traces of water-soluble manganese present, and the level of exchangeable manganese was also low. Much larger amounts of both these forms of soil manganese were present in the more acid soils. After steaming

TABLE V

Soil	Total N %	Total manganese p.p.m.	Unsteamed					Steamed				
			pH	p.p.m. Manganese				pH	p.p.m. Manganese			
				Water-soluble	Exchangeable	Easily reducible	Total* available		Water-soluble	Exchangeable	Easily reducible	Total* available
Field ...	0.081	56	3.81	0.8	12.2	12.7	25.7	3.75	1.4	15.1	7.4	23.9
Maiden ...	0.240	476	4.16	30.9	103.5	146.4	280.8	3.96	63.0	87.5	129.9	280.4
,, ...	0.243	314	4.22	56.7	56.6	66.8	180.1	3.56	67.1	58.9	48.5	174.5
,, ...	0.200	376	4.62	39.7	124.9	134.1	298.7	4.51	81.6	103.1	112.5	297.2
,, ...	0.414	965	4.82	1.5	2.2	475.7	479.4	4.73	4.6	8.5	466.3	479.4
Field ...	0.335	312	5.13	1.7	19.1	185.6	206.4	4.99	7.3	29.2	170.0	206.5
Garden ...	0.363	961	5.51	Trace	3.8	617.2	621.0	5.19	5.6	22.1	587.3	615.0
,, ...	0.340	322	6.00	0.8	1.6	49.3	51.7	5.88	3.1	38.3	8.9	50.3
Field ...	0.322	528	6.18	Trace	2.9	333.8	336.7	6.10	0.8	12.0	322.8	335.6
Glasshouse	0.583	374	6.19	—	1.1	32.5	33.6	6.19	0.9	1.7	28.0	30.6
,,	0.311	160	6.55	—	0.5	115.7	116.2	6.49	—	1.8	115.8	117.6
,,	0.199	595	6.73	—	1.6	85.9	87.9	6.62	1.9	1.7	81.4	85.0
Field ...	0.263	370	6.88	—	0.8	86.9	87.7	6.74	0.6	2.5	87.3	90.4
,, ...	0.142	665	7.08	—	1.0	404.7	405.7	6.93	1.2	4.4	398.9	404.5
Garden ...	0.427	1049	7.14	—	1.4	478.2	479.6	7.02	0.9	4.4	462.8	468.1
Glasshouse	0.154	685	7.38	0.8	1.1	103.3	105.2	7.30	1.6	1.3	103.1	106.0
,,	0.191	703	8.19	—	—	98.5	98.5	8.22	0.5	2.3	91.9	94.7
,,	0.180	495	8.37	—	—	63.6	63.6	8.36	—	2.4	64.0	66.4

*Calculated as the sum of water-soluble, exchangeable and easily reducible manganese.

an increase in water-soluble manganese was observed in 16 out of the 18 soils. This increase did not, however, exceed 2 p.p.m. in soils with pH values greater than 6. Appreciable increases in exchangeable manganese were produced on steaming in the majority of the soils having a pH of less than about 6. In two of the most acid soils there was a decrease; this was, however, accompanied by a marked increase in the water-soluble manganese. In soils with pH values greater than 6 there were only small increases in exchangeable manganese after steaming.

The easily reducible fraction of the soil manganese in general decreased after steaming. The total available manganese contents of the soils (*i.e.*, the sum of the water-soluble, exchangeable and easily reducible manganese) before and after steaming are very similiar. The two sets of data are, in fact, not significantly different at the 5% probability level.

In the unsteamed soils, the total available manganese ranged between 8.9 and 79.4% of the total manganese. The values for the six glasshouse soils were, with one exception, much lower than those for the maiden, garden and field soils, and did not exceed 16%. The total available manganese is significantly correlated with the total soil manganese. The correlation coefficient for all 18 soils was 0.726; on omitting the six glasshouse soils a value of $r=0.914$ was obtained for the 12 remaining soils. Both of these values are significant at the 0.1% level. The easily reducible manganese is also highly significantly correlated with the total soil manganese ($r=0.787$ for 18 soils and 0.934 for 12 soils).

The increase in water-soluble manganese on steaming is closely correlated with the exchangeable manganese in the unsteamed soils. Correlation coefficients for 18 and 12 soils are 0.974 and 0.972 respectively. There is no apparent relationship, however, between the exchangeable manganese in the unsteamed soils and the increase in water-soluble plus exchangeable manganese after steaming. Correlation coefficients relating the increases in water-soluble and exchangeable manganese after steaming and the total soil manganese, the total available manganese or the easily reducible manganese in the unsteamed soils are all non-significant. There is also no apparent relationship with the total nitrogen content of the soils. Plots of the increases in the various forms of manganese after steaming and the original soil pH do not indicate linear relationship. The diagrams do suggest, however, that hyperbolic relationships might be involved. Transformation of the increases to the logarithmic scale do give a relationship approaching linearity. The correlation coefficients r relating the $\log_{10}$ increase in water-soluble manganese after steaming and the pH are -0.712 ($P = 0.001$) and -0.580 ($P = 0.05$) for 18 and 12 soils respectively. A similar logarithmic relationship between the increase in water-soluble plus exchangeable manganese after steaming and soil pH is significant for 18 soils ($r = -0.589$, $P = 0.01$), but not significant when the six glasshouse soils are omitted.

Discussion

Various investigators have reported changes in water-soluble and exchangeable manganese after heat treatment of soil [8,9]. McCool[10] observed an increase in water-soluble manganese in soil autoclaved at 240°F for three hours. Fujimoto and Sherman [11], working with highly manganiferous Hawaiian soils, reported increased concentrations of exchangeable manganese of up to 3000 p.p.m after autoclaving soil for three hours at 15-lbs. pressure. More recently Aldrich and Martin[12] have reported increases in water-soluble plus exchangeable manganese after autoclaving soil at 15-lbs. pressure for two hours. It seems likely that the severity of the steaming treatments adopted by the above authors would have rendered the soils almost sterile. In the present investigation the steaming procedure was mild and comparable to that used commercially.

It is apparent from the results that soil pH is an important factor in determining the amounts of water-soluble and exchangeable manganese which will be released on steaming. Only small increases were observed in the neutral and alkaline glasshouse soils of the Lea Valley. It is well known that in many neutral and alkaline soils the fixation of added manganese in an unexchangeable form proceeds rapidly [13,14]. In alkaline soils the increases in exchangeable manganese produced after steaming also

disappear rapidly. In contrast, much larger increases in water-soluble and exchangeable manganese were found in acid soils after steaming. Moreover, there was a further increase on incubation of such soils, a result which may be due to the activity of micro-organisms, it having been shown that reduction of manganese in soils can be brought about by biological agencies[15].

The rapidity with which the exchangeable manganese content of an acid soil can fall after liming has been shown by Heintze[16]. A similar effect was observed in the present experiments. Liming an acid soil also reduced the amounts of water-soluble and exchangeable manganese released on subsequent steaming. The longer the period between liming and steaming the more pronounced was the reduction; a considerable decrease in water-soluble manganese was apparent, however, only a week after liming.

Other soil properties such as the total soil manganese, the easily reducible fraction, or the total nitrogen content appear to have no influence on the amount of water-soluble or exchangeable manganese released on steaming.

The total available manganese, *i.e.*, the sum of the water-soluble, exchangeable and easily reducible forms, is not apparently significantly altered by steaming. The easily reducible fraction, does however, invariably decrease on steaming, part of it having been rendered water-soluble or exchangeable.

Since considerable amounts of water-soluble and exchangeable manganese may be released on steaming soils with a pH lower than about 6, instances of manganese toxicity may in some cases be expected among plants grown in such soils after partial sterilization. This aspect of the problem is dealt with more fully in a subsequent section of this report. Above a soil pH of about 6 only small increases in water-soluble and exchangeable manganese were observed after steaming, although in many cases the soils contained considerable amounts of easily reducible manganese. In such soils there is little risk of manganese being increased to the toxicity level. However, steaming such soils may correct an incipient tendency to manganese deficiency. Fujimoto and Sherman[17] have concluded that the increased availability of manganese after steaming may be the cause of either the beneficial or harmful effects on plant growth in heated soil. They do, however, point out that this conclusion is not in complete agreement with all of their results. For instance, in a soil low in manganese there was a reduction in growth after steaming, whereas a soil higher in manganese gave an increased yield.

B. Growth of young tomato plants in acid maiden soils after steaming

The higher levels of water-soluble and exchangeable manganese found in certain acid maiden soils after steaming have been described above. In view of these results it was considered desirable to investigate the effect of these soils on plant growth. The effect of the following soil treatments was examined: — (1) steamed, (2) steamed plus superphosphate, (3) steamed plus lime, (4) steamed plus lime and superphosphate, and (5) unsteamed. All fertilizer additions were at the 0.5% rate. Tomato seedlings, variety Potentate, at the 2–3 leaf stage were potted up in these mixtures, five plants constituting each treatment.

After seven days the first signs of injury began to appear on the plants growing in soils from which lime had been withheld. The youngest leaves became chlorotic, while at the same time the oldest leaves were directed downwards with the leaflets curling under. This was followed by a dark purplish brown necrosis of the veins of the oldest leaves together with the appearance of occasional brownish-purple necrotic patches in the adjacent tissue. Three weeks after potting all the youngest leaves of the plants growing in steamed soil to which superphosphate alone had been added were extremely chlorotic and the plants were stunted. (Plate 1). Further examples of chlorosis associated with high levels of manganese are shown in Plate 2. Apart from a slight chlorosis of the youngest leaves about a week after potting which persisted for two or three days, the plants growing in soil to which lime had ben added appeared green and healthy.

Thirty days after potting the plants were cut down at soil level and the tops dried in a forced draught oven at 80°C. Data for mean height, fresh and dry weights and percentage dry matter are recorded in Table VI. It will be seen that of the steamed treatments those plants receiving superphosphate alone were markedly stunted and were only a little heavier than plants grown in unsteamed soil. Plants grown in soil to which lime had been added were taller, heavier and had a higher dry matter content than those grown in the other soil treatments.

TABLE VI

Soil treatment	Mean height cms.	Fresh weight per plant g.	Dry weight per plant g.	% Dry Matter
Steamed	14.5	10.9	1.01	9.3
Steamed plus 0.5% superphosphate	11.9	7.7	0.62	8.1
Steamed plus 0.5% lime	18.8	15.2	1.60	10.5
Steamed plus 0.5% lime and 0.5% superphosphate	18.9	18.5	2.02	10.9
Unsteamed	10.2	5.5	0.47	8.6

An examination of the root systems of the plants at the time of harvesting revealed no indication of root damage except in plants grown in the unsteamed soil. Addition of superphosphate alone to the steamed soil appeared to reduce root development.

The soil from the pots of each treatment was combined and a sample taken for pH determination. A further sample was analysed for water-soluble and exchangeable manganese. These results are shown in Table VII. Where lime was added the soil pH was increased to about 7, but the addition of superphosphate alone depressed the pH. Compared to the unsteamed soil the content of water-soluble plus exchangeable manganese was higher in the steamed soil, somewhat less in the presence of added superphosphate and approximately halved where lime had been added.

TABLE VII

Soil treatment	pH	Water-soluble plus exchangeable manganese p.p.m.
Steamed	5.11	84.4
Steamed plus 0.5% superphosphate	4.80	50.2
Steamed plus 0.5% lime	7.04	31.3
Steamed plus 0.5% superphosphate and 0.5% lime	6.82	31.9
Unsteamed	5.30	62.1

Samples of plant material from the various treatments were analysed for total nitrogen, phosphate, potash, calcium and manganese. The results are shown in Table VIII, expressed as mg. uptake per plant, together with the percentage of manganese in the oven-dry tissue.

TABLE VIII

Soil treatment	mg. uptake per plant					%
	N	P_2O_5	K_2O	CaO	Mn	Mn
Steamed	30.2	7.6	51.0	42.8	4.92	0.49
Steamed plus superphosphate	23.1	11.3	43.2	31.6	2.26	0.36
Steamed plus lime	46.9	6.6	64.6	80.0	2.13	0.13
Steamed plus lime and superphosphate	44.2	29.9	77.8	86.5	1.56	0.08
Unsteamed	16.1	7.6	27.5	25.9	1.34	0.29

PLATE 1. Tomato plants grown in a steamed acid maiden loam with added lime and superphosphate (*left*) and with added superphosphate only (*right*)

PLATE 2. Tomato plants grown in a steamed acid maiden loam with no amendments (*right*) and with added superphosphate (*left*)

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Plants growing in steamed soil to which lime had been added took up considerably more nitrogen and potash than did those grown in the other soil treatments. Their uptake of manganese was, however, similar to that of the plants grown in steamed soil plus superphosphate. If the manganese values are expressed as percentages of the oven-dry tissue, the manganese present in the plants grown in steamed soil plus superphosphate was four to five times as much as in plants grown in soil to which lime as well as superphosphate had been added. It is of interest to note that the calcium uptake of the plants grown with added superphosphate was less than those grown in the steamed soil alone.

A set of data similar to the above is available for another soil which released a considerable amount of water-soluble and exchangeable manganese on steaming. The visual symptoms of injury were similar to those described above but were much less severe; the addition of superphosphate, however, again aggravated the symptoms. Analysis of the oven-dry tissue showed that in general the uptake of nitrogen, phosphate and potash followed a similar pattern to that shown previously. The uptake of calcium and manganese was, however, somewhat different. The analyses for these elements, together with the soil pH and water-soluble plus exchangeable manganese contents at the time of harvesting, are shown in Table IX. It will be seen that in this experiment the uptake of manganese by plants growing in steamed soil to which superphosphate alone had been added was considerably more than in any of the other treatments. The addition of lime markedly reduced the manganese uptake. The calcium uptake of plants grown in the steamed soil with added superphosphate was much higher than in the previous experiment. There was also more water-soluble plus exchangeable manganese in the soil treated with superphosphate than in any of the other treatments.

TABLE IX

Soil treatment	pH	Water-soluble plus exchangeable Mn, p.p.m.	mg. uptake per plant		% Mn
			CaO	Mn	
Steamed	5.16	5.53	49.5	3.94	0.28
Steamed plus superphosphate ...	4.80	6.07	72.7	5.64	0.37
Steamed plus lime	7.47	13.9	90.5	1.07	0.06
Steamed plus lime and superphosphate	6.95	42.3	83.3	1.21	0.07
Unsteamed	4.92	38.3	41.6	3.52	0.24

Discussion of results

The results of several investigations, mainly during the last decade, have shown that manganese toxicity is apparently one of the main causes of plant injury associated with soil acidity[18,19,20,21,22,23]. Aluminium toxicity and lack of available calcium, magnesium or phosphate may also affect plant growth on some acid soils[24,25,26].

The visual symptoms of injury observed in the present experiments are similar to those described by Hewitt[20] for manganese toxicity in tomatoes. High levels of manganese were found, in both soils and plant tissue, and it thus appears that this is an instance of steaming injury due to manganese toxicity.

It is of interest that, in the present experiments, addition of superphosphate appeared to aggravate the symptoms of manganese toxicity. Bortner[27] found that phosphate fertilization of acid soils had a beneficial effect on tobacco plants suffering from manganese toxicity. Manganese toxicity in swedes has also been prevented by applications of superphosphate and basic slag[28]. Morris and Pierre[29], however, did not confirm these results; they found that the growth of *Lespedeza* plants suffering from manganese toxicity was further depressed by the addition of phosphate to the culture solutions. It appears that the unfavourable effect of superphosphate in the present experiments is due to a lowering

of the soil pH, as a result of which the water-soluble manganese was increased. Thus it was found that incubation of an acid soil with superphosphate for seven days resulted in an increase in the water-soluble manganese of 36 p.p.m., while at the same time the soil pH decreased from 4.04 to 3.87. Various workers have shown that applications of calcium sulphate had an unfavourable effect on soil pH and on manganese toxicity[24,30,31]. Hewitt[19], however, found in sand culture experiments that with increasing calcium supply (as the sulphate) the symptoms of manganese toxicity became less severe. In the present investigation, plants with a high uptake of manganese accompanied by a high calcium uptake showed only very mild toxicity symptoms.

Liming the soil after steaming had a pronounced beneficial effect. Apart from a transient mild chlorosis the plants were healthy and grew normally, This is in accord with the well known beneficial effect of liming on manganese toxicity. Although the plants grown in steamed soil treated with lime appeared healthy, their uptake of manganese was quite appreciable, and in one case was comparable to that of plants grown in soil treated with superphosphate and showing marked toxicity symptoms. Olsen[32] has shown in this connection that optimal absorption of manganese occurs at pH 6–7.

An acid maiden soil after liming and steaming would be expected to produce considerable amounts of ammonia[33]. This may contribute to the alleviation of the toxicity as it has been shown that ammonium ions have a favourable effect in alleviating manganese toxicity in beans[34] and flax[35].

From the results described it is apparent that partial sterilization of acid soils may produce conditions injurious to the growth of young plants. Complete control can, however, be effected by judicious liming.

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4. BORON IN THE NUTRITION OF TOMATOES

by

J. H. L. MESSING

In the course of previous studies[1] of micro-nutrient deficiencies with various crops in sand culture the effects of boron deficiency have been particularly marked. Whilst we ourselves have never encountered typical symptoms of acute boron deficiency in commercial tomato crops, numerous instances of boron deficiency of tomatoes have been recorded both in America and on the Continent; the relevant literature will be reviewed subsequently when a full account of the present studies is presented for publication. It thus appeared worthwhile to study the boron-requirements of the tomato in some detail, as even in the absence of visual symptoms of acute deficiency the boron status of commercial tomato crops might in some cases prove to be sub-optimal. Experiments on the growth of tomato plants at various levels of boron were accordingly undertaken at Cheshunt Research Station in 1954. Samples of plant tissue collected during these experiments were subsequently analysed for boron content at the new Institute during 1955. In the account which follows both the sand-culture studies of 1954 and the analytical results of 1955 are described.

Experimental methods

Seed of variety Potentate was sown in soil on January 28th, 1954. At the stage of two rough leaves the plants were transferred to five-inch plastic pots filled with silica sand, and supplied with complete nutrient solution containing 0.2 p.p.m. boron. On April 13th, the cultures were leached with several lots of distilled water and the plants were transferred to two-gallon glazed earthenware pots. From then on nutrient solutions with graded quantities of boron were used.

In the first part of the experiment, subsequently referred to as Series A, boron was added to the nutrient solution at concentrations of 0.001, 0.004, 0.008, 0.02, 0.2 and 2 p.p.m., the first four concentrations representing deficiency levels and 2 p.p.m. being considerably in excess of requirements. Each treatment was replicated four times, and two control plants were grown without any added boron.

In addition to the plants of Series A, further plants from the same batch were grown with nutrient solution containing 0.2 p.p.m. boron until May 20th. Four additional treatments were then started, namely, 0.008, 0.015, 0.030 and 0.060 p.p.m. of boron. At this date the first trusses had begun to swell, the second and third trusses had set, the fourth trusses were flowering and the fifth were just showing. Two plants were grown at each level of boron, this part of the experiment being designated Series B.

Results

Series A

Measurements of the height of all plants, and of the length of the leaf immediately above the first truss, were made on May 20th. As shown in Table I, the mean height of the plants increased with the levels of added boron up to 0.2 p.p.m.; length of leaf showed a similar increase up to the highest level of boron.

TABLE I

Measurements of height, leaf length and fresh weight for plants of Series A

p.p.m. boron in nutrient solution	Average of four plants on May 20th		One plant from each treatment on May 28th		
	Height of plant in cms.	Overall length (cms.) of leaf immediately above the first truss	Fresh weight (gms.)		
			Total**	Laminae	Petioles
—	45.0*	22.4*	187.1*	86.9*	37.3*
0.001	57.0	27.2	235.2	106.2	43.6
0.004	70.3	30.8	374.8	178.1	88.3
0.008	80.5	31.1	388.4	166.5	82.3
0.02	97.0	37.1	459.3	175.9	101.1
0.2	98.0	42.1	563.6	229.1	152.6
2.0	95.3	44.8	473.6	177.1	129.9

* Average of two plants ** Excluding fruit

A week later one plant was removed from each treatment, and fresh weights of the plants excluding root, and also of laminae and petioles separately, were recorded (Table I). In each case the fresh weights increased with increasing boron level in the nutrient solutions up to a concentration of 0.2 p.p.m., but fell again at 2 p.p.m. The relative growth of the plants at this stage of development (27/5/54) is shown in Plate 1.

The first indication of boron deficiency was chlorosis of the youngest leaves, starting at the base of each leaflet. This was noted in all treatments below 0.2 p.p.m. of boron approximately 10 to 14 days after the beginning of the differential treatments. In the complete absence of added boron all growth stopped at this time and the growing point died within a few days. The lower concentrations of boron allowed some continuation of growth; the shape of the leaves was, however, affected, the petioles being shorter than on plants receiving more boron, thus bringing the leaflets closer together. The leaflets lacked their usual smoothness and were thicker, distorted and curled. Both stems and petioles became brittle; when removing side shoots it was noted that these broke off extremely easily, and difficulty was experienced when training the plants up the strings.

The main growing point died on every plant supplied with nutrient solution containing less than 0.2 p.p.m. boron, the figure below showing the number of days between the start of the treatment and the recorded death of the growing point of the last plant in each group.

Boron concentration p.p.m.	Time (in days)
–	21
0.001	24
0.004	34
0.008	34
0.020	60

PLATE 1. Growth of tomato plants at concentrations of 0, 0.001, 0.004, 0.008, 0.02, 0.2 and 2 p.p.m. of added boron. (*Photographed 27/5/1954*).

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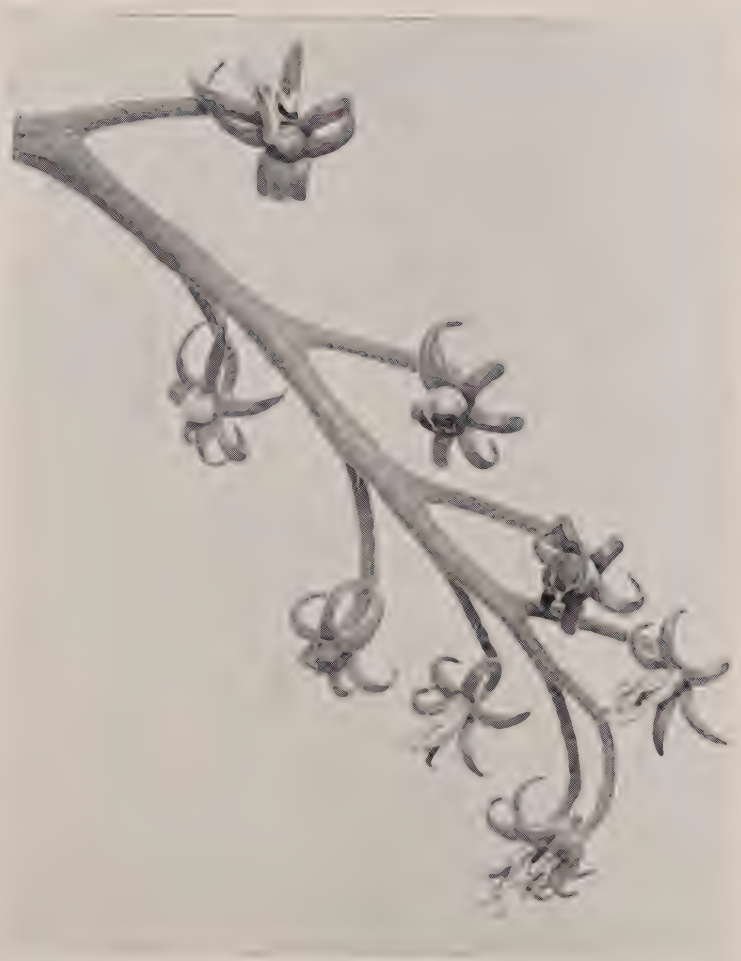

PLATE 2A. Truss from a plant grown at 0.005 p.p.m. of boron, showing failure of fruit to develop.

PLATE 2B. Truss from a plant grown at 0.02 p.p.m. of boron; the two largest fruit show prominent ridging, and the others show a corky ring partly surrounding the calyx.

Any new growth subsequent to the death of the main growing point showed curling of the leaves and defective, rudimentary laminae. Older leaves had irregular orange and purple tinted patches, the veins showing strong purple pigmentation.

At a concentration of 0.02 p.p.m. of boron the deficiency symptoms were less marked, and for some time it appeared that the plants were recovering from the initial chlorosis of the youngest leaves. Shortening and brittleness of the petioles were observed. At this level of boron in the nutrient solution the effects of the deficiency were more pronounced on the fruit than on the vegetative organs. Growth was slower than at the 0.2 p.p.m. level, and stopped completely about five weeks later than at the lower levels of boron.

At a concentration of 2 p.p.m. of boron a brown edge-scorch appeared on the older leaves in the third week, and slowly progressed up the plants until at the end of the season almost all leaves were affected. Growth of the plants was, however, only slightly reduced, and only a few of the oldest leaves dried up completely.

No fruit was formed in the absence of added boron or at a concentration of 0.001 p.p.m. Fruit on plants grown in solutions containing 0.004 and 0.008 p.p.m. was malformed, cracking at an early stage, turning brown and drying up. At a level of 0.02 p.p.m. of boron some fruit was normal at first, and only developed symptoms of "corky back" when swelling; practically all fruit formed at this concentration showed "corky back," and even when this appeared in a mild form the fruit was roughly shaped with prominent ridges. As shown in Table II, the fruit in this treatment was larger than at 0.2 p.p.m. of added boron; at the latter concentration the fruit was well shaped and of good average size. When boron was supplied in excess the shape of the fruit remained good, but the total crop and the size of individual fruits decreased somewhat below that of the 0.2 p.p.m. treatment. The appearance of fruit developed at concentrations of 0.008 and 0.02 p.p.m. of added boron is shown in Plate 2, A and B respectively.

TABLE II

The total weight of fruit per plant, the number of fruits and the average weight per fruit for Series A

p.p.m. boron in nutrient solution	Average weight of fruit per plant (gms.)	Average number of fruit per plant	Average weight per fruit (gms.)
0.02	2312	27	85.6
0.2	3578	58	62.1
2.0	3319	59	56.6

Series B

Symptoms of boron deficiency appeared rapidly at a concentration of 0.008 p.p.m., and were similar to those described for series A. At 0.015 and 0.030 p.p.m. necrosis on the middle leaves, similar to that described by Hester[2], was noted by the end of June. Acute chlorosis of the youngest leaves and death of the main growing points followed. At 0.060 p.p.m. boron the plants grew well until the middle of September, but after reaching the 12th truss chlorosis was noted, growth ceased and the growing points died. At this stage of the experiment plants in the 0.2 and 2.0 p.p.m. treatments were stopped above the 12th truss.

At a concentration of 0.008 p.p.m. the fruit was badly affected in the same way as described for Series A and also in the Annual Report for 1953. Fruit which had set before the beginning of the treatment developed "corky back," and no fruit set above the fifth truss. At both 0.015 and 0.030 p.p.m. of boron "corky back" occurred on the lower trusses, and the fruit was large and course. At a concentration of 0.060 p.p.m. occasional fruits showed "corky back" in the later part of the season. The fruit was slightly smaller than at the 0.2 p.p.m. level.

The average weight of ripe fruit from each truss is recorded in Table III.

TABLE III

	p.p.m. boron in nutrient solution				
	0.008	0.015	0.030	0.060	0.2
	Weight of fruit in grams				
Truss 1	451.6	385.0	600.6	400.0	601.5
,, 2	610.3	419.7	399.7	402.1	685.7
,, 3	568.8	856.2	657.3	536.7	906.4
,, 4	154.9	163.3	381.8	260.0	296.8
,, 5	—	152.0	350.4	543.0	448.8
,, 6	—	15.4	268.5	360.6	313.0
,, 7	—	—	15.9	101.8	133.9
,, 8	—	—	—	48.9	69.9
,, 9	—	—	—	35.4	50.9
,, 10	—	—	—	15.4	42.6
,, 11	—	—	—	—	39.9
,, 12	—	—	—	—	—

The total weight of fruit per plant, the number of fruits and the average weight per fruit are shown in Table IV.

TABLE IV

p.p.m. boron in nutrient solution	Average weight of fruit per plant (gms.)	Average number of fruit per plant	Average weight per fruit (gms.)
0.008	1786	20	89.3
0.015	1991	28	71.1
0.030	2674	36	74.3
0.060	2704	50	54.1
0.2	3589	58	61.9

Uptake of boron by the plants

Samples of laminae and petioles from plants in Series A harvested on May 28th, and previously referred to in Table I, were dried for 24 hrs. at 80°C. in an oven with forced air circulation. Samples of ripe fruit collected from all plants in each treatment during the first week in July were also dried. (48 hours) for analysis.

The boron content of the samples was determined by the curcumin method of Dible, Truog, and Berger[3]. Ground and dried tissue (0.2–0.4 g.) was ashed at 550–580°C. and the ash dissolved in 10 mls. of 0.1 N hydrochloric acid. After making up to a volume of 50 mls. in a soda-glass volumetric flask a 1 ml. aliquot was used for colour development. A set of standards was prepared with each batch of tests, the colours being measured in a "Spekker" absorptiometer with 4 cm. cells.

The dry matter and boron contents of the laminae and petioles from Series A are summarized in Table V. The percentage of dry matter in laminae and petioles decreased with increasing supply of boron in the nutrient medium. with the exception of the excess level. It should be added, however, that the slight increase in dry matter content of the laminae of plants grown with nutrient solution containing 2 p.p.m. boron may be partly attributed to marginal scorch present on the older leaves. The boron content of the laminae was relatively low at all concentrations of boron in the nutrient solutions below 0.2 p.p.m., but increased very markedly at 0.2 and 2.0 p.p.m. The boron content of laminae from the 0.02 p.p.m. treatment is, at first sight, anomalously low. It may be noted, however,

that these plants formed the only group in Series A which, while exhibiting deficiency symptoms, produced any mature fruit and continued to grow up to the time of sampling. The petioles showed far less variation in boron content than did the laminae.

TABLE V

The content of boron and dry matter in leaves from Series A

p.p.m. boron in nutrient solution	Laminae		Petioles	
	% dry matter	p.p.m. boron	% dry matter	p.p.m. boron
—	15.8	22	10.6	16
0.001	15.2	22	10.1	23
0.004	12.2	24	9.1	14
0.008	12.5	24	9.7	20
0.02	12.6	16	8.8	33
0.2	11.8	107	8.8	38
2.0	13.2	328	9.1	43

The dry matter and boron content of ripe fruit from both Series A and B are recorded in Table VI. The dry matter content of fruit from both series was lowest at the lowest levels of boron in the nutrient solutions. The boron content of the fruit increased with increasing levels of added boron; the values are lower than for petioles but show relatively greater variation in relation to nutrient levels.

TABLE VI

The content of boron and dry matter in fully ripened fruit from Series A and B

p.p.m. boron in nutrient solution	% dry matter	p.p.m. boron in dry matter
Series A		
0.02	5.32	3.4
0.2	5.48	11.8
2.0	5.63	17.7
Series B		
0.008	5.43	3.8
0.015	5.79	4.7
0.030	5.85	7.0
0.060	6.08	7.6
0.2	5.48	11.8

Discussion of results

The need for an adequate level of boron in the nutrition of tomato plants was clearly demonstrated in the present series of experiments. The visual symptoms of deficiency varied with the amounts of boron supplied. Thus chlorosis and distortion of the leaves, death of the growing points and failure of the fruit to set or develop were clearly established. At 0.02 p.p.m. some chlorosis of the leaves was noted, but the most significant effect was on the weight and quality of fruit ripened. Plants grown at a concentration of 0.2 p.p.m. boron made good growth throughout, and this concentration is considered to be at or slightly below the optimum level under the conditions of these experiments.

The percentage of dry matter in the foliage of tomato plants (Table V) was highest for plants grown in the absence of added boron, and decreased with increasing boron concentration to a minimum value corresponding approximately to optimal growth at a concentration of 0.2 p.p.m. of boron in the nutrient solutions. At a higher concentration (2.0 p.p.m.) of boron the dry matter content of the leaves increased, accompanied by considerable edge-scorch of the older leaves. These results could be

explained by greater accumulation of carbohydrates in the leaves of boron-deficient plants; the role of boron in the translocation of sugars has been reviewed by Gauch and Dugger[4]. The results for dry matter content of tomato foliage in the present investigation are similar to those obtained by Brennan and Shive[5] for the lower leaves of tomato plants, but these authors found a reversed trend in the upper leaves.

The percentage of dry matter in the fruit (Table VI) tended to increase with increasing boron concentrations in nutrient solution, and indirectly supports the theory of reduced translocation of carbohydrates from leaves to fruit in plants inadequately supplied with boron. Majewski and Majewska[6] also found some increase in the dry matter content of tomato fruit with increasing supply of boron, and noted a tendency for the dry matter content to reach a maximum at levels of boron just below those giving optimal growth. This is in close agreement with our present results given in the second part of Table VI.

It is apparent from Table V that, when boron is supplied in excess of growth requirements, it accumulates in the laminae rather than in the petioles. Laminae are thus considered to be the best material for further studies of boron uptake by tomato plants, though the fruit may also provide data of some interest. The distribution of boron in the laminae of soil-grown plants in relation to leaf position on the plant will be described in a later report.

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5. UNIFORMITY TRIALS IN TOMATO HOUSES B1–4, C1–4

by

G. W. WINSOR and J. N. DAVIES

An extensive programme of soil and tissue analysis has been undertaken in connection with uniformity trials in Blocks B and C instituted by the Research Sub-Committee. These glasshouses were treated with stable manure at the rate of 20 tons per acre, but no fertilizers at all were applied either as base or top dressings. A summary of the analytical results for soil samples taken at the end of the cropping season of 1954 is now presented; the samples were stored until laboratory facilities were established and assistant staff trained during 1955.

Sampling and analysis

Each of the houses contained 56 plots, making 448 composite soil samples in all. Within each house the plots were numbered from 1 in the north-east corner to 28 in the south-east, and from 29 in the south-west to 56 at the north-west. Plots 1 and 56 consisted of three single rows and plots 28 and 29 one row of tomato plants (variety E.S.5); all other plots consisted of two rows of plants, making a total of ten plants per plot. A layer of straw covered the paths and generally surrounded the two plants in front of the heating pipe in each plot; this covering was removed when the samples were taken. Each soil sample consisted of nine borings made with an auger to a depth of nine inches.

Measurements of pH and pC were made on soil suspensions prepared at a water/air-dry soil ratio of 2.5: 1 after shaking for one hour. "Available" phosphate and potash were extracted with 0.5 N-acetic acid at a soil/extractant ratio of 1: 40. Phosphate was determined colorimetrically and potassium with a flame-photometer. Organic carbon was estimated by the method of Walkley and Black. Values for phosphate, potash and organic carbon have been expressed on the basis of oven-dry soil. Moisture equivalents were also determined on some samples, using a soil-testing centrifuge.

Results

The full data for the 448 plots are too extensive to be reported here. The range of values for each house, and for all eight houses combined, is shown in Table I; the corresponding mean values are given in Table II, and the coefficients of variation in Table III. The moisture equivalents determined on eight samples from each house are given in Table IV.

TABLE I

Range of analytical values for soil samples from houses B1–4, C1–4

	pH	pC	Available* P_2O_5, %	Available* K_2O, %	Organic Carbon, %
B1	6.04–7.92	3.63–4.30	0.0008–0.0038	0.0037–0.0148	0.87–1.21
B2	5.66–7.83	3.68–4.37	0.0007–0.0023	0.0044–0.0100	0.86–1.27
B3	5.90–7.92	3.83–4.40	0.0006–0.0034	0.0049–0.0152	0.85–1.21
B4	5.78–7.86	3.71–4.35	0.0008–0.0049	0.0060–0.0169	0.90–1.28
C1	5.64–7.32	3.40–4.30	0.0004–0.0025	0.0044–0.0176	0.90–1.36
C2	5.94–7.60	3.67–4.28	0.0004–0.0026	0.0050–0.0138	0.89–1.24
C3	6.40–7.86	3.58–4.17	0.0005–0.0039	0.0048–0.0155	0.86–1.28
C4	5.78–7.40	3.60–4.09	0.0004–0.0035	0.0055–0.0137	0.91–1.23
B1–C4	5.64–7.92	3.40–4.40	0.0004–0.0049	0.0037–0.0176	0.85–1.36

* Soluble in 0.5N–acetic acid

TABLE II

Mean analytical values for soil samples from houses B1–4, C1–4

	pH	pC	Available* P_2O_5, %	Available* K_2O, %	Organic Carbon, %
B1	7.03	3.94	0.0014	0.0073	1.04
B2	6.92	4.08	0.0012	0.0073	1.06
B3	6.90	4.13	0.0012	0.0083	1.04
B4	6.88	3.99	0.0018	0.0100	1.08
C1	6.56	3.94	0.0011	0.0087	1.08
C2	6.80	3.97	0.0010	0.0070	1.03
C3	7.00	3.89	0.0015	0.0091	1.05
C4	6.68	3.85	0.0012	0.0079	1.07
B1–C4	6.85	3.97	0.0013	0.0082	1.06

* Soluble in 0.5N-acetic acid

The values for pH show considerable variability, as noted in previous surveys[1]; the soil appears to be relatively poorly buffered. Values for phosphate and potash are very low throughout, and thus presented certain analytical difficulties; the customary ratio of soil to extractant was, however, retained in order to facilitate comparison with any subsequent analytical studies. It is to be hoped that

TABLE III

Coefficients of variation for houses B1–4, C1–4

	pH	pC	Available* P_2O_5	Available* K_2O	Organic carbon
B1	6.1	3.6	33.6	33.3	7.6
B2	6.6	3.8	28.3	18.4	6.6
B3	5.0	3.8	44.2	30.6	6.9
B4	5.3	2.9	49.4	25.5	6.6
C1	6.2	3.0	37.3	26.9	9.3
C2	5.9	3.6	48.0	20.1	7.4
C3	4.6	3.2	48.0	27.7	8.2
C4	6.4	3.3	40.0	19.7	5.8

* Soluble in 0.5N-acetic acid

TABLE IV

Moisture equivalent of soil from houses B1–4, C1–4

Plot	B1	B2	B3	B4	C1	C2	C3	C4
1	18.7	18.6	18.3	17.9	18.7	18.6	18.3	18.2
14	19.0	18.5	18.9	18.4	18.5	18.9	18.2	18.6
15	18.9	19.0	18.3	17.9	18.7	18.9	17.9	18.6
28	18.1	18.2	17.9	18.1	18.4	18.7	17.6	18.4
29	17.5	18.0	17.9	18.3	17.8	17.8	17.4	18.3
42	18.2	18.3	17.7	18.1	19.0	18.6	17.4	18.3
43	18.6	18.6	18.7	19.0	19.1	18.8	18.8	18.6
56	18.5	18.3	18.0	18.0	18.9	17.9	18.2	18.3
Mean	18.4	18.4	18.2	18.2	18.6	18.5	18.0	18.4

the observed variations in phosphate and potash may become of relatively little practical significance when fertilizers are applied in future years. The content of organic matter in the soil, though low throughout, shows some increase over the previous year, presumably owing to the application of stable manure. The results for moisture equivalent show very little variation between samples over the whole area.

The results still await detailed statistical examination elsewhere. A preliminary examination within the Department shows significant variations between house means for pH, pC, available phosphate, available potash and organic carbon.

Correlations between crop yield and soil analyses

Full crop data for the 448 plots were obtained by the crop recorders. The range of values within each house, together with the mean for each house, is given in Table V. Correlation coefficients relating crop yield and the analytical data for pH, phosphate, potash and organic carbon are presented in Table VI.

One house (B4) in B block and three houses in C block showed significant correlations between crop yield and pH, the yields tending to rise with increasing pH values; a similar relationship holds for C block as a whole but not for B block. Positive correlations were also obtained between yield and available phosphate in houses B1 and B4, C1, C2 and C3; the correlations were also significant for both B and C blocks. Only in house B1 was a significant correlation obtained between crop yield and "available" potash in the soil; this relationship is, however, significant both for B block and for C block taken as a whole. Houses C1 and C2 showed significant positive correlations between yield and the amount of soil organic matter, and the correlation remains highly significant for C block as a whole. On considering all eight houses together, correlations between crop yield and soil pH,

TABLE V

Summary of crop data for B and C Blocks during 1954, expressed in lbs per plant

House	Range	Mean
B1	3.7–10.9	6.5
B2	3.8– 9.8	5.7
B3	3.5– 9.0	5.6
B4	3.8–12.4	6.2
C1	3.2– 8.2	5.8
C2	3.4– 7.7	5.0
C3	4.0– 8.6	6.0
C4	4.4– 9.2	5.9
B1–C4	3.2–12.4	5.8

TABLE VI

Correlation coefficients relating crop yield and soil analyses

House	No. of Plots	pH	Available P_2O_5 %	Available K_2O %	Organic Carbon %
B1	56	–0.026	0.454***	0.478***	0.011
B2	56	–0.023	0.098	–0.016	0.019
B3	56	0.089	0.251	0.229	0.246
B4	56	0.294*	0.376**	0.074	0.188
C1	56	0.559***	0.510***	–0.025	0.313*
C2	56	0.517***	0.537***	0.181	0.498***
C3	56	0.312*	0.335*	0.040	0.262
C4	56	0.235	0.159	0.181	0.083
B1–B4	224	0.096	0.355***	0.203**	0.109
C1–C4	224	0.404***	0.409***	0.164**	0.328***
B1–C4	448	0.258***	0.391***	0.186***	0.215***

* P=0.05 ** P=0.01 *** P=0.001

"available" phosphate and potash, and organic carbon were all positive and significant at P=0.001, the highest numerical value being that for "available" phosphate.

It is of interest that only one house of the eight sampled showed a significant correlation between crop yield and "available" potash; preliminary examination of data for the content of potassium in leaf samples collected during the following season indicates significant relationships with crop yield. It may also be noted that no significant correlations between yield and soil analyses were found for houses B2, B3 and C4, whereas the remaining houses show correlations with at least two of the soil determinations in each case. In assessing the value of the data for crop yields it must be appreciated that very considerable difficulty was encountered in preparing the borders in time for planting the 1954 crop, and that considerable disease was evident among the plants. It is also unfortunate that the soil sampling could not be commenced before the end of September owing to delays in the delivery of containers for storage of the soil samples. The soil samples are thus not fully representative of conditions during the earlier stages of growth, particularly with regard to the values for potassium.

In addition to the results now presented for soil samples collected during 1954, both soil and tissue samples were taken in 1955. Analyses of these latter samples will be completed during 1956.

REFERENCES

[1] Winsor, G. W., Davies, J. N. & Massey, D. M., *Rep. Exp. Res. Sta. Cheshunt*, 1953, 61.

7. Plant Physiology

1. GENERAL

Plant Physiology suffered complete disruption of the programme in progress at Cheshunt consequent on the removal to the new site. In the absence of an experimental glasshouse and with laboratories primarily designed for chemical investigations, it was necessary to improvise expedients which it is hoped will be temporary.

Work on growth studies of tomato roots has been suspended. Meanwhile it is interesting to note that the trends in root growth established at Cheshunt in 1951 and since confirmed in the following three years, have been observed at the Dutch Research Station, Naaldwijk. Presumably further developments of this line of research will appear from there.

A small Dutch light glasshouse was erected at the south end of the new laboratory block and adjacent to one of the Plant Physiology laboratories, so that work using the recording, null-method tensiometer on a potted plant could continue. Nylon tubing has been found a suitable substitute in place of capillary glass and copper tubing for the mercury manometer and connection in tensiometers.

Growth analysis observations on the tops of tomato plants have been made using one of the new vinery-type glasshouses. Unfortunately temperatures within the house proved very variable due to the unsuitable heating system.

Comparison was made, on a total of five widely spaced plants, of the growth of the different organs (stem, leaves and fruit) between plants with all laterals removed and those in which all laterals were allowed to continue indefinite growth, sub-laterals only being removed. In the remainder of the house crop records only were taken, plant by plant, the plants being grown with all laterals removed or with the "truss laterals" immediately below each truss allowed to grow, and stopped after successively fewer trusses on each lateral. At mid-summer half these plants were removed and replaced by plants at the normal stage of development for planting out. These were given similar pruning treatment. The results are undergoing analysis.

2. FURTHER OBSERVATIONS ON THE GROWTH OF THE ROOT AND THE SHOOT OF THE TOMATO PLANT

by

A. J. COOPER

Introduction

It is rather surprising that applied research workers seem to have neglected to make a detailed definition of the growth of the tomato plant in the environment of a commercial type glasshouse throughout a growing season since such a definition would appear to be a logical pre-requisite to the planning of attempts to influence growth. Such attempts must be based on a fundamental knowledge of growth if they are to be successful.

An example of the need to define the growth before attempting to influence it is provided in the Cheshunt Annual Report for 1954 (page 18, I. Tomatoes (b) Pruning and Training) since a study of the growth analysis data presented below shows that, if it is desired to increase yield by leaving in laterals, these laterals must be fruit-bearing laterals and not laterals that normally bear little or no fruit. A knowledge of the morphology of the tomato plant would have shown in advance the fallacy of retaining alternate laterals on developing shoots above the sixth truss in an attempt to increase yield and, in particular, the fallacy of retaining the lateral above the sixth truss.

Technique

A study of the growth of the roots of the tomato in relation to the growth of the other organs of the plant was begun in the Department of Plant Physiology a few years ago, and a report on the first year's work appeared in 1953 (Leonard 1953, Rep. Exp. Res. Sta. Cheshunt 39, 62).

Since then the work has been continued and during 1954 detailed measurements of the growth of all the organs of the plant—leaves, shoots, roots and fruit—were made and form the basis of this report.

Measurements were made from March to July only, as the shoots had reached the roof of the aeroplane-type glasshouse by the beginning of July.

The variety used was Potentate, and the plants were set out in the glasshouse border on March 12th. Four groups of four plants each were grown against the glass-lined sides of two trenches. Through these glass panels, which were 2ft. 8in. deep and 4ft. wide, observations on root growth were made. Two rows of four plants were sited 9in. distant from the glass panels, and the other two rows were 13½in. distant.

The present report deals with the plants in which all the laterals on the main stem were allowed to develop, the second order laterals developing on the first order laterals being removed as soon as they appeared. No leaf was removed from either the main stems or the laterals until the majority of the lamina had lost its green colour and was largely dry and brown. Normal commercial practice was followed in the watering and manuring of the plants.

Measurements were made at weekly intervals of the length of the roots visible in the glass panel, of the length of the leaves (stated by Goodall to be a valid criterion of leaf area—1945 Ann. Bot. N.S. 9,101) and of the shoots, and of the diameters of the fruit. These diameter measurements were converted to the cubes of the radii in order to provide an estimate of the increase in fruit volume on the plants. By the time the recording of data was discontinued none of the fruit was sufficiently ripe to pick although some of the fruit was nearly mature.

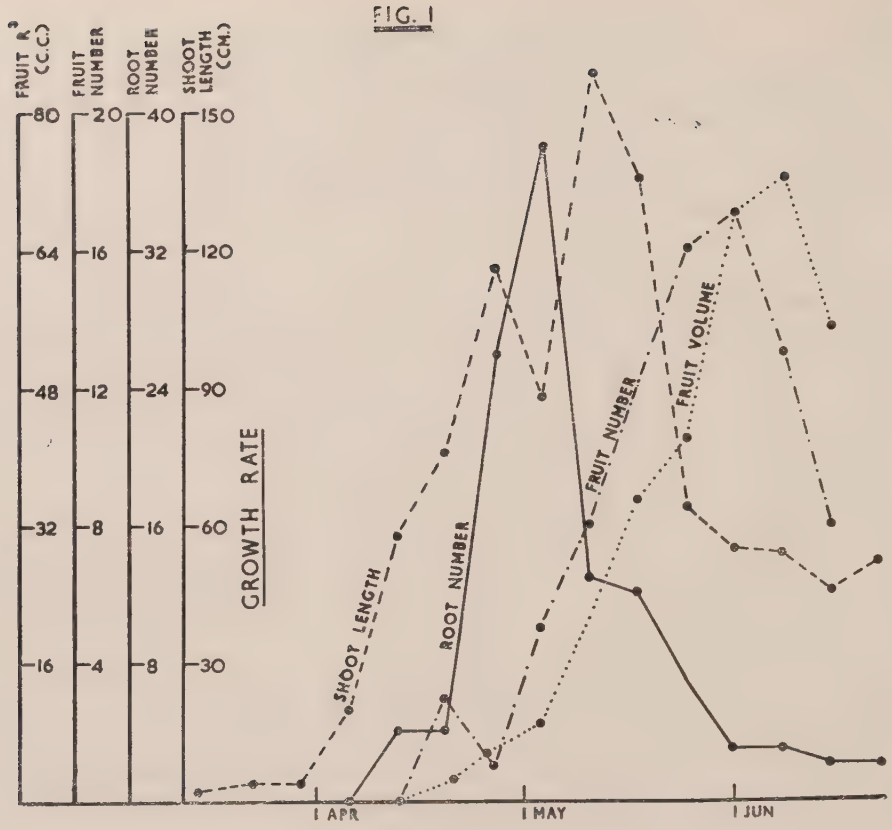
Time Relationships in the Growth of the Shoots, Roots, Fruit and Leaves

The mean weekly absolute rate of shoot extension growth of one group of four plants is shown in Fig. 1, together with the mean weekly rate at which new roots from these plants appeared.

There was an initial lag in shoot extension growth for approximately two weeks after planting, *i.e.*, until the end of March. From the end of March until early May the weekly rate of shoot extension growth increased fairly steadily until a maximal rate was reached in early May. There then occurred, about the middle of May, a sudden pronounced decrease in the rate of growth, and from late May to the end of the period under consideration (*i.e.*, late June) growth continued at a relatively low rate. From late May to late June the growth rate continued to decline but the decline was much less rapid than it had been during the two previous weeks.

The first roots from the plants appeared in the glass panel in early April, and the weekly rate at which new roots appeared increased rapidly until a maximal rate was reached by early May. During May the weekly rate of appearance of roots declined steadily until a very low level was reached by the end of the month, and during June very few new roots appeared.

The similarity in Fig. 1 between the curves of shoot length and the number of new roots appearing is quite striking, the changes with time in the rate of shoot extension growth being very similar to the changes occurring in the rate of appearance of new roots. The development of the root system, however, was either affected slightly before, or at the same time as, the growth of the shoots, in that the sharp decline from the maximal rate of appearance of new roots appeared to occur one week before the decline in shoot extension growth.

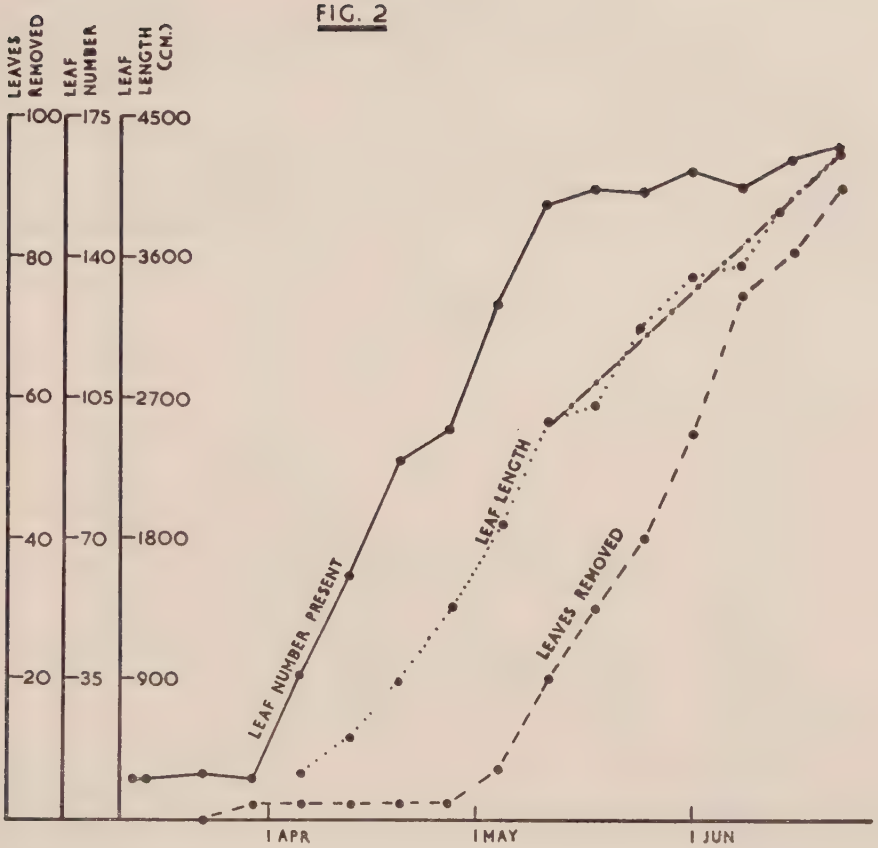


Also shown in Fig. 1 is the mean weekly rate of appearance of fruit up to the time that picking began, and the mean weekly rate of swelling of the fruit on the plant as estimated by changes in volume.

Fruit appeared at a steadily increasing weekly rate from approximately mid-April until a maximal rate was reached in late May. This was followed by a decline in early June. The weekly rate of increase in the total volume of fruit borne on the plant rose steadily to a maximum in early June, and this also was followed by a decline. The changes in the development of the fruit on the plants and the changes in the appearance of new fruit on the plant occurred either in close sequence or together, since the maximal rate of appearance of new fruit was attained one week before the maximal rate of increase in fruit volume.

The data for leaf growth for the same group of four plants are shown in Fig. 2 (the mean used is the total growth at any time divided by the number of plants). Until the end of April very few leaves were removed at all. The leaf number present on the plant increased at a rapid rate (after an initial lag following planting) until early May. After this date the leaf number present continued to increase but at a much reduced rate. Similar changes in the total leaf length of the plants occurred in early May. Up to this date the curve of leaf length was exponential in form; from early May onwards, as shown in Fig. 2 by the calculated polynomial of closest fit (chain link), the subsequent portion of the curve was linear. As can be seen in Fig. 2 leaves were removed from the plants at a fairly constant rate from the beginning of May to the end of the period under consideration. It is of interest that the beginning of senescence of the lower leaves in early May coincided with the decline in the appearance of new roots in the glass panel.

FIG. 2



Thus all the organs of the plant—leaves, shoots, roots and fruit—showed sudden, pronounced changes in development between early May and early June. First there was a decrease in the rate at which new roots appeared in the glass panels, and then senescence of the lower leaves began. These changes occurred at about the same time in early May. Approximately one week later a decline occurred in the rate of shoot extension growth, and in the rate of increase in leaf number present and a change took place in the weekly increase in total leaf length. The third group of changes occurred approximately three weeks later in early June when there was a decrease in the rate of appearance of fruit followed by a decrease in the rate of fruit swelling. Thus from early May to early June there was a decrease in the rate of development of all the organs of the plants, the roots being first affected, then the leaves and the shoots and finally the fruit.

Examination of the development of the fruit trusses on the main stems of the plants and of the the extension growth of the shoots arising in the axils of the leaves immediately below these trusses (*i.e.*, the "truss laterals") provides further evidence of marked changes in development during the month of May.

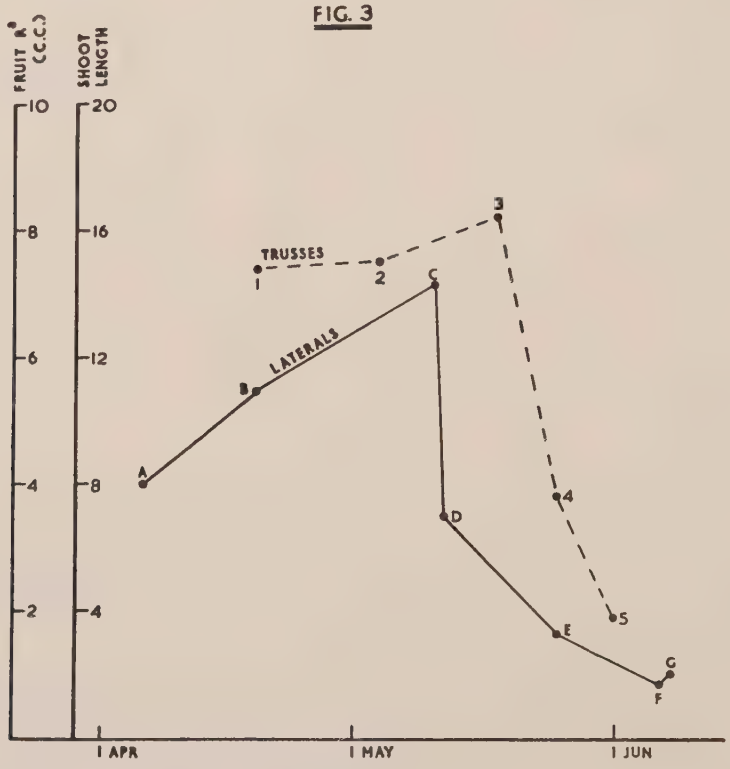
In Fig. 3 is shown the mean weekly rate of swelling of the fruit in each of the first five trusses on the main stem of one of the plants during the first three weeks' swelling of each truss. The trusses are indicated by the numbers 1 to 5. The mean weekly rate of extension growth, during the first three weeks' growth, of the shoots arising in the axils of the leaves immediately below the first seven trusses on the main stem is also shown. These "truss laterals" are indicated by the letters A to G. The mean weekly rates of development are shown plotted on the approximate dates on which visible development of the fruit truss or "truss lateral" was first observed.

The initial development of the successive "truss laterals" was more rapid the nearer it was to early May that the shoot first appeared, the most vigorous being the shoot (C) that appeared in early May in the axil of the leaf below the third truss. "Truss laterals" developing subsequently showed a pronounced decline in initial vigour.

Similarly the third truss, which first began to swell in mid-May, had the most rapid initial development, later produced trusses showing a marked decline in vigour.

Thus further evidence is provided for the contention that there occurred between early May and early June a check in the rate of development of the tomato, the check affecting the shoots and then the fruit.

FIG. 3



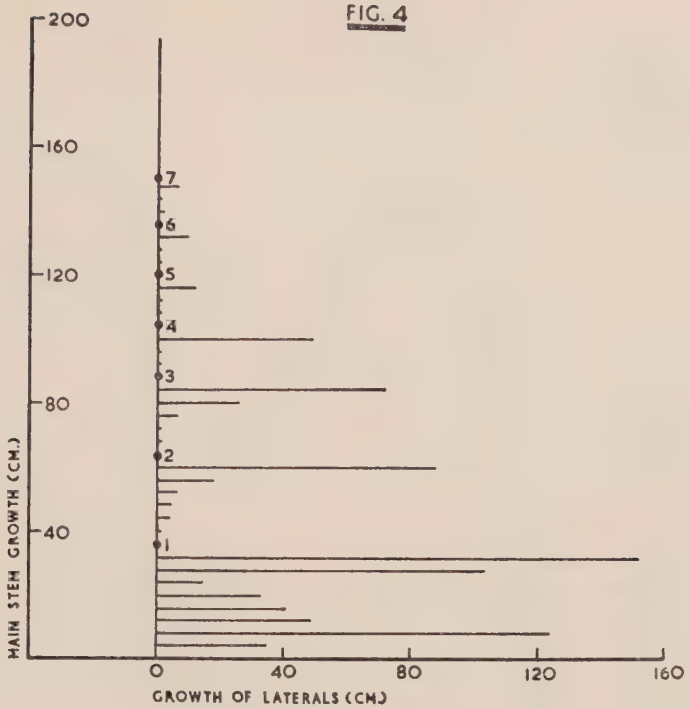
Cycle of Vigour of Development of Laterals

In Fig. 3 the "truss laterals" only were selected for presentation from the total number of laterals since there is a cyclic pattern of vigour of development of laterals with progress up the main stem.

In Fig. 4 are shown the lengths attained by the main stem and all the laterals of one of the plants by late June. The length of the main stem is indicated by a vertical line, the length of the axillary shoots by horizontal lines and the positions of the trusses on the main stem are shown by the numbers 1 to 7.

There was a regularly recurring pattern of vigour of lateral growth related to the position of the trusses on the main stem, the most vigorous laterals being those that arose in the axils of leaves immediately *below* trusses. The growth of laterals arising in the axils of leaves immediately *above* trusses was practically inhibited, while intermediate laterals exhibited intermediate degrees of vigour. All of the laterals below the first truss bore fruit but the laterals above the first main stem truss exhibited a similar pattern of vigour in the production of fruit, since only the laterals arising in the axils of leaves immediately below trusses bore fruit.

FIG. 4

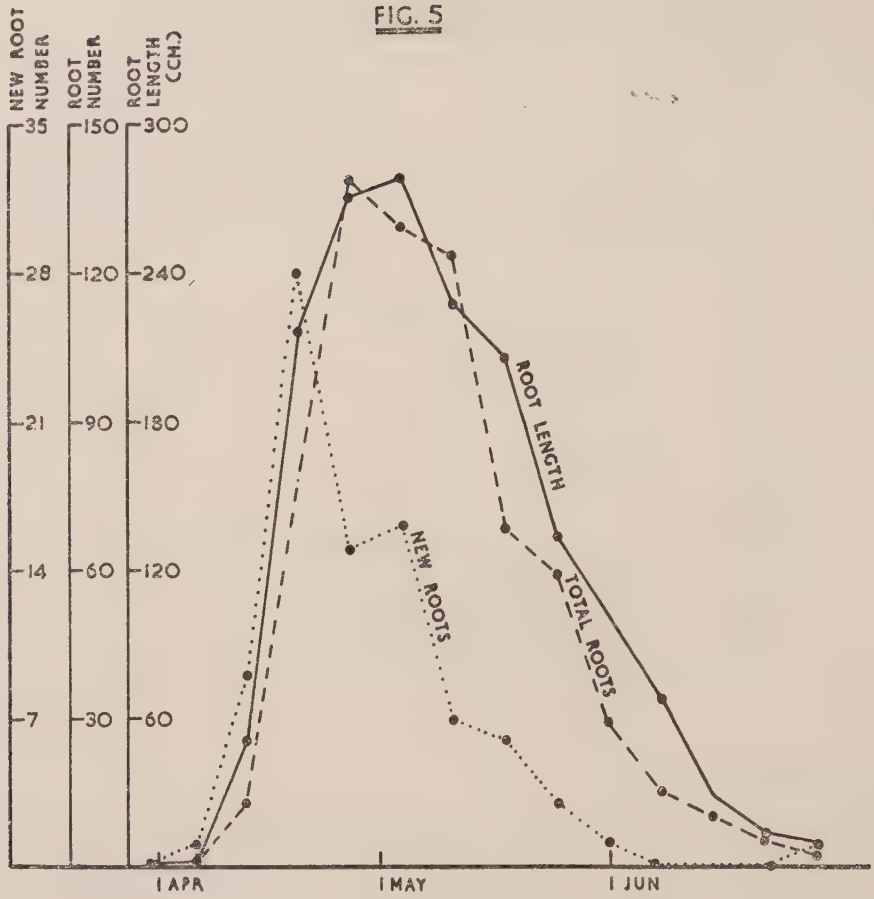


Criteria of Root Growth

A phenomenon observed in the analysis of the root growth data was that the curves showing the changes in the development of the root system from April to July were similar whether the criterion of development used was (a) the number of new roots appearing in the glass panel each week, (b) the total number of roots present in the panel or (c) the total length of the roots visible. It can be seen from Fig. 5 that each of these three curves rose steeply to a maximum in late April/early May and then declined steadily to a low level. The number of new roots reaching the panel attained a maximum first; approximately one week later the total number of roots present in the panel was maximal and one week after that the maximal length of root visible in the panel was attained. Thus, except for a slight displacement in time, similar changes in the development of the root system were reflected no matter which of the three criteria was used.

It was found that the growth of the majority of the roots along the face of the glass panels occurred for not less than one, and not more than thirteen, days after the roots reached the glass. It was not possible to define the limits of the duration of the visible growth of the roots precisely as measurements were made at weekly intervals, but it is possible to say definitely that, for the majority of the roots, growth did not continue for more than thirteen days after the roots reached the glass panel, and to suggest that the period of growth may have been less than thirteen days. Thus the use of root length as a criterion of root development could be expected to show the same trends as the use of the total number of roots visible in the panel except that, because of the growth of the roots along the face of the glass for an approximately constant number of days, the peak of total root length would be attained between one and thirteen days after the peak of total root number. As shown in Fig. 5 this is in fact what happens, the peak of root length occurring approximately one week after the peak of total root number.

FIG. 5

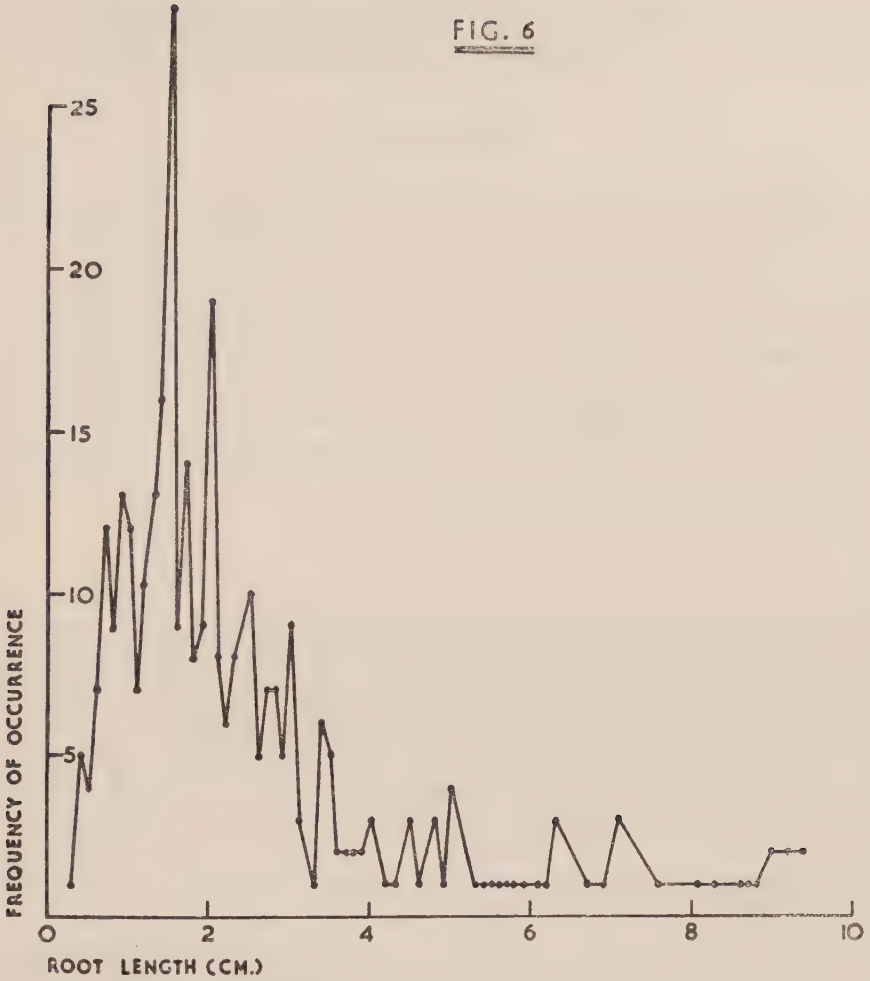


Thus total root length was presumably measuring the same change in development as total root number except that when root length was the criterion used the extension growth of the roots along the face of the glass was introducing a lag of approximately one week into estimations of changes with time in the development of the root system.

That the use of root length as an indication of changes in development was inferior to the use of total root number was further suggested by the fact that the majority of the roots grew along the face of the glass for a similar distance. Fig. 6 shows the frequency curve for the final lengths of the roots visible in the panel against which the plants were growing. Of the roots, 76% grew along the glass for a fairly similar distance, *i.e.*, between 0.6 and 3.0 cm.

It was found in four random samples of twenty-four roots each, that roots remained visible in the glass panel for varying lengths of time up to one hundred and fifty nine days. Thus because of persistance of this order it would be expected that changes in the development of the root system would occur later and be less sharply defined when total root number was the criterion used than when the number of new roots reaching the glass in given intervals of time was used. This is, in fact, what happens as is shown in Fig. 5.

FIG. 6



Thus the conclusion can be drawn that the number of new roots appearing in the glass panel in a given interval of time is the most sensitive of the three criteria of changes in root development, in that it gives the most immediate indication of changes since it does not include the lag effect outlined above that occurs when the criteria of total root length and total root number are used. It would appear to assess the same aspect of development that both total root length and number measure and it also has the advantage of being far less laborious and time consuming in the recording of data, thus reducing observer error due to fatigue in work on root growth.

SUMMARY

1. Further growth studies of the tomato have been made and showed that (a) all the organs of the plant underwent sudden pronounced changes in development between early May and early June, (b) there was a cyclic pattern of vigour of development of laterals that was related to the position of the trusses on the main stem.
2. As a criterion of trends of growth in the root system the number of new roots appearing in a glass panel has been shown to be more sensitive than the total number of roots present or the total length of roots present.

3. A NOTE ON THE SPATIAL VARIABILITY OBSERVED IN TENSIOMETERS IN A BORDER OF GLASSHOUSE TOMATOES

by

H. R. B. HACK

The variability of soil moisture tension as indicated by tensiometers (mercury manometer type)[1] is being studied. Some results typical of the 1953 records are now given (shown graphically in Figures 2 and 3) from work carried out at Cheshunt Experimental Station.

The variety grown was E.S.5, and the general treatment of the crop followed commercial lines with watering by hose. After watering, all instruments fell to closely the same tension.

The instruments were set out in three blocks of 12. Each block comprised four tensiometers at each of three depths: four inches, eight inches and two feet. The plan of one block is shown in Figure 1. The plants are shown as circles, the tensiometers as crosses. The numerals 1, 2, 3 and 4 (see also Figures 2 and 3) indicate the position of the tensiometers across the plant row. No. 1 position was mid-way in the narrow row, No. 2 was at the foot of a plant and Nos. 3 and 4 were placed at successive intervals of six inches into the broad row.

Results

1. *Variability*

The standard error per instrument at four inches depth estimated for observations on each of the following occasions—the evening of the 10th and the morning of the 11th April, and the evening of the 4th June—after eliminating variability associated with blocks and variability associated with position was $\pm$ 4 cm. mercury. This estimate is based on six degrees of freedom.

There was no significant difference between blocks for the April example, but in the June data the means per block (18, 26, 29 cmHg) were significantly different at nearly the 1% level. The curves in Figure 3 are derived from the data from only two blocks, the plant in the block with the lowest mean being diseased.

The variability associated with position of tensiometer in relation to the plant was highly significant.

The variability for the eight inch depth shows a similar pattern but is less extreme. The fluctuations over the watering cycle at the two feet depth were very small being generally 1–2 cmHg with a maximum of about 5 cmHg.

2. *Spatial trends at different times*

Figures 2 and 3 illustrate three important observations.

I In April (Figure 2) the tension rose to a high level first at the foot of the plant (position 2) and then at the mid-way point (position 1) between the rows about 12 inches apart. At the same time the tension remained low where the plant rows were widely spaced (positions 3 and 4).

II The situation was reversed in June (Figure 3). The tension was then high in the broad row (positions 3 and 4) and lower at the foot of the plant (position 2) and in the narrow row (position 1).

III Diurnal fluctuations of the tensiometer occur at the foot of the plant in each plot (Figure 2) in such a way that the tension is high in the evening and lower in the morning. The fluctuations do not occur to the same extent in the more distant instruments. Such fluctuations have now been frequently observed but only occur where considerable gradients of this kind exist. The drop in tension overnight seems to be the result of water movement from regions of low to regions of high tension, occurring when transpiration is reduced. If this movement occurs the *quantity* of water that migrates can only be estimated where the moisture content/tension characteristic curve of the particular soil is available.

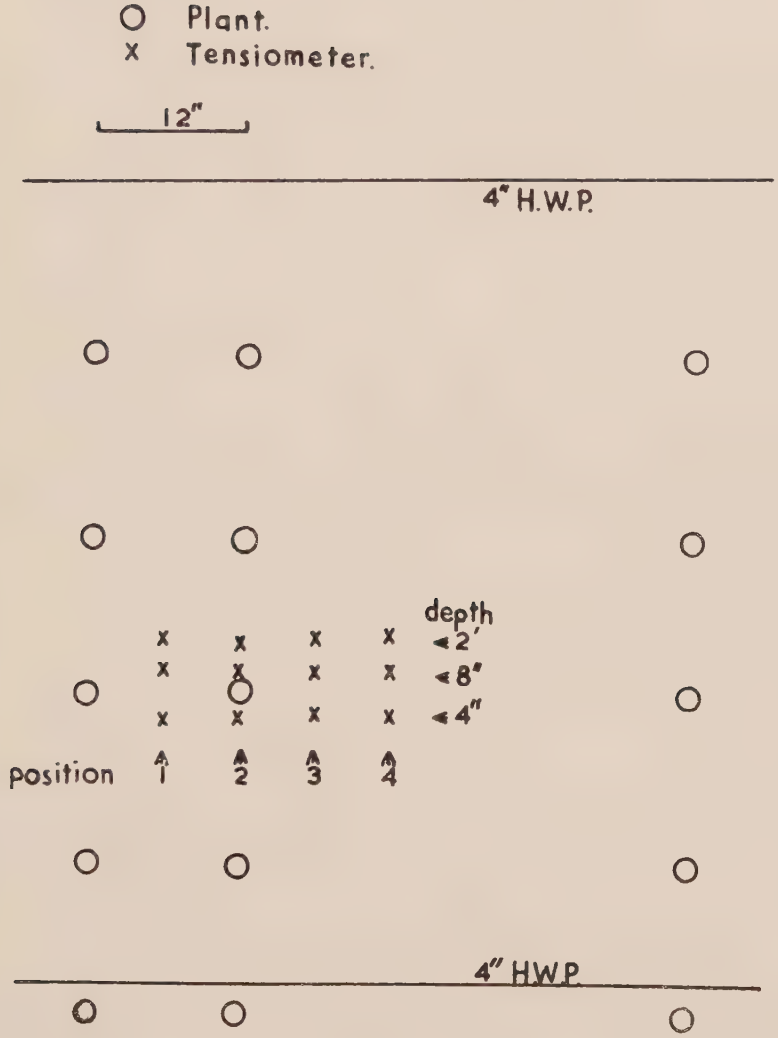
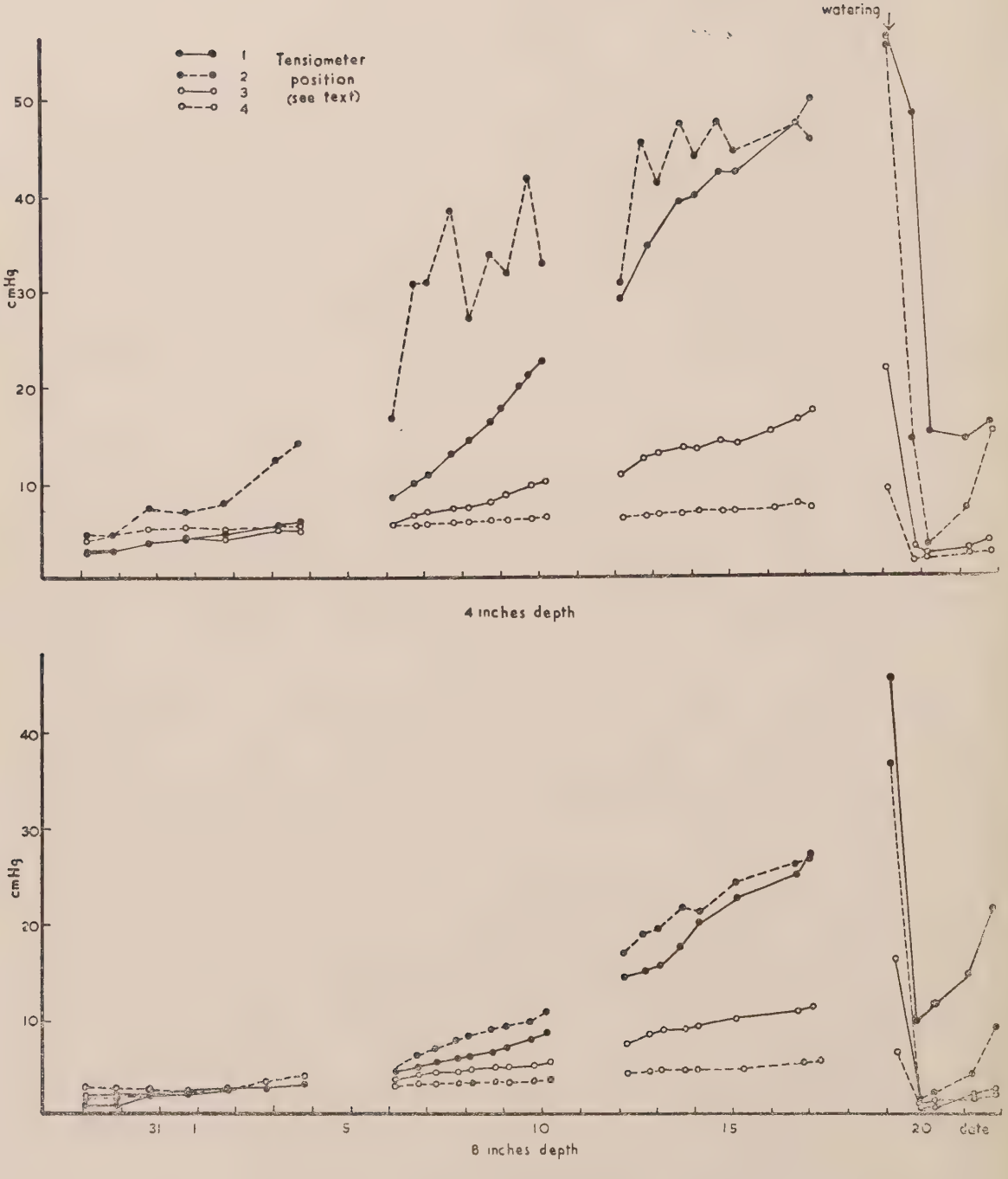


Fig. 1



Tensiometers, March/April

FIG. 2

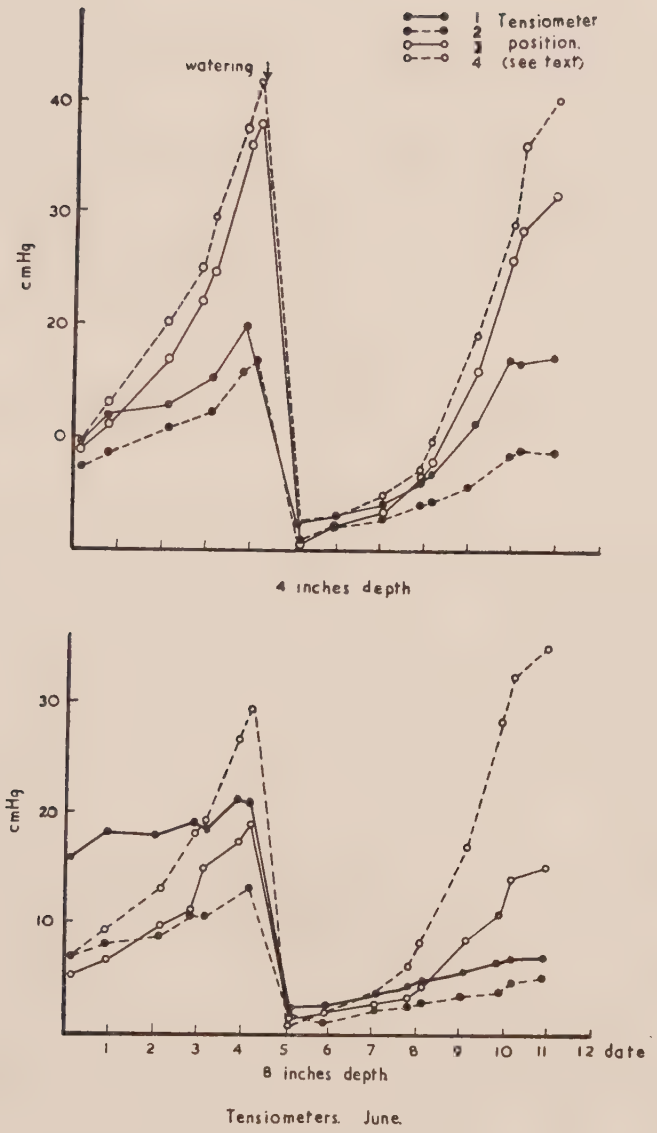

1 Tensiometer
2 position.
3 (see text)
4
watering
40
30
20
0
cmHg
4 inches depth
30
20
10
cmHg
1 2 3 4 5 6 7 8 9 10 11 12 date
8 inches depth
Tensiometers. June.

FIG. 3

There are some conclusions relevant to cases where a moisture tension distribution of this type with spatial trends varying with time occurs.

1. It would be extremely misleading to base a watering regime on one tensiometer mid-way in the space between plants where tension is low while the tension at the foot of the plant is high.
2. The siting of tensiometers must take into account variation of spatial trends with time. For instance, if it were desired to prevent the tension in the border rising above a certain level it might be necessary to have an instrument at the foot of the plant for use at one stage and mid-way between plant rows for use at another. This problem requires investigation as a function of variety, planting distance and growing conditions.
3. The use of an arithmetic mean tension to characterise the level of moisture stress at any one time may not be valid and may inadequately utilize the information in the data if this does in fact give an indication of spatial variability of root activity.
4. The trends shown by tensiometers should be related to observations on the root development of the plant with particular consideration of the root death phase already studied by E. R. Leonard and reported in the Cheshunt Report for the year 1953.

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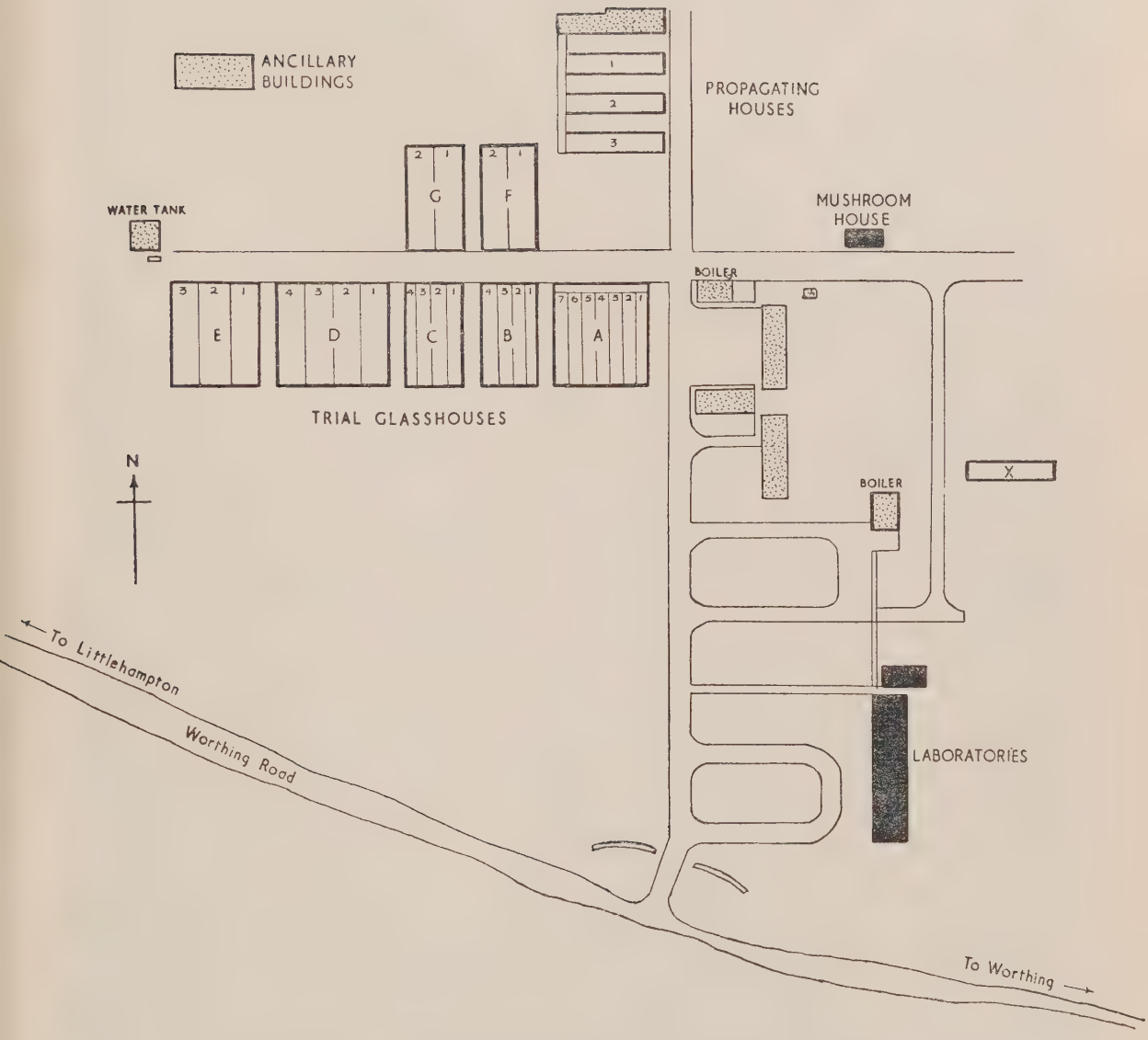

Layout of the Institute's Glasshouses, Laboratories and other buildings

THE JOURNAL OF HORTICULTURAL SCIENCE

THE JOURNAL OF HORTICULTURAL SCIENCE, which is sponsored by the Long Ashton Research Station and the East Malling Research Station, welcomes contributions on horticultural science from Research Institutes at home and abroad. Papers for publication and all communications should be sent to the Editors at East Malling Research Station, Maidstone, Kent.

The current VOLUME 32 (1957) contains papers from both the sponsor Research Stations, from the John Innes Horticultural Institution, Scottish Horticultural Research Institute, National Vegetable Research Station, Reading and Nottingham Universities, Wye College, Ditton Laboratory, the N.A.A.S, and from the Transvaal and the West African Cocoa Research Institute. Papers accepted for this and for Volume 33 deal with the culture of fruit, flowers and vegetables in the open and under glass, and cover a wide list of subjects, among them, propagation, nutrition, factors affecting the flowering of raspberries and chrysanthemums, pests, and diseases, including viruses. There is an interesting series of papers on the effects of water regimes on tomatoes and lettuces, and a study of growth trends of the tomato plant through the growing season. A device for automatic control of day length is described.

The Journal is issued in quarterly parts and is published by Messrs. Headley Brothers, 109 Kingsway, London, W.C.2., to whom intending subscribers should apply. The subscription rates for the *current volume* are 50 shillings per volume (rate for Canada and the U.S.A., $7.00) of 15 shillings for a single number. The Editors regret that the rate for Volume 33 (1958) must be raised to 60 shillings per volume (rate for Canada and the U.S.A. $8.50) or 20 shillings for a single number.

The Glasshouse Crops Research Institute from the air

The Laboratories

GLASSHOUSE CROPS RESEARCH INSTITUTE

ANNUAL REPORT

1956

LITTLEHAMPTON · SUSSEX

The abbreviated title of this Report as given in the World List of Scientific Periodicals is:—

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GLASSHOUSE CROPS RESEARCH INSTITUTE

The Glasshouse Crops Research Institute was established on the 8th September, 1953, as a company limited by guarantee, but without share capital, under the Companies Act of 1948. Its registered office is at Littlehampton, Sussex, where the main research station is being developed.

In the Memorandum of Association the principal object for which the Institute has been established is laid down as follows:

> "To promote scientific research bearing on the cultivation of glasshouse crops and mushrooms, and of bulbs, flowers and shrubs grown in the open, and on matters ancillary thereto."

The Institute is managed by a Governing Body consisting, at present, of fourteen members including the Chairman, Mr. T. Ainslie Robertson. Of these, six are well-known commercial growers who represent the branch of horticultural industry served by the Institute, and six are eminent scientists. The Governing Body is appointed by the Minister of Agriculture, Fisheries and Food, one of whose Senior Education and Advisory Officers is also a member.

The Institute is financed almost entirely by grants from the United Kingdom Treasury. From 1st April, 1956, these will be administered by the Agricultural Research Council which exercises general supervision over the Institute's staffing and research programme.

The Institute has a subscription scheme whereby growers may associate themselves with its work. For a small annual subscription growers obtain certain privileges which enable them to take a closer and more personal interest in the research that is being carried out on their behalf. Full particulars of this scheme may be obtained from the Secretary of the Institute.

GLASSHOUSE CROPS RESEARCH INSTITUTE

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GLASSHOUSE CROPS RESEARCH INSTITUTE

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W. F. Bewley, C.B.E., D.Sc. (Dunelm), V.M.H. (*until 30.9.56*)
F. W. Toovey, O.B.E., B.Sc. (Lond.), A.R.C.S., A.I.C.T.A. (*from 1.10.56*)

Director-Designate

F. W. Toovey (*from 1.1.56 to 30.9.56*)

Plant Physiology

E. R. Leonard, D.Sc. (Lond.), A.R.C.S.
H. R. B. Hack, B.A. (Cantab.)
A. J. Cooper, B.Sc. (Lond.), Ph.D. (Reading)

Assistants (*Scientific*)

Mrs. B. Cooper, Miss A. Holmwood, Mrs. B. Millard

Chemistry

G. W. Winsor, B.Sc. (Bristol), Ph.D. (Lond.), A.R.I.C.
J. N. Davies, B.Sc., Ph.D. (Lond.)
J. H. L. Messing, B.Sc. (Wales)
P. B. Flegg, B.Sc. (Reading), A.R.I.C., M.I. Biol.
D. M. Massey, B.Sc. (Bristol)
M. I. E. Long.

Assistants (*Scientific*)

Miss I. Warman, Miss A. Pennicott, Miss J. Parsons, Miss W. Stoner, P. Adams

Plant Breeding

L. A. Darby, B.Sc. (Wales)

Plant Pathology

P. H. Williams, B.Sc. (Lond.)
Miss M. H. Ebben, M.A. (Cantab.)
R. Howles, B.A., Ph.D. (Cantab.)
Mrs. J. D. E. Hack, A.B. (Vassar College), B.A. (Cantab.) (*until 30.9.56*)
Miss O. M. Stone, M.A., Ph.D. (Cantab.)
Miss D. G. Gandy, B.Sc., M.Sc. (Lond.)

Assistants (*Scientific*)

R. Pawley, Miss P. Shoesmith, Miss J. Kerner

Entomology

N. W. Hussey, B.Sc. (Wales), Ph.D. (Edin.) (*appointed 1.5.56*)
W. J. Parr, M.I.Biol.
Miss C. D. Crocker (*until 31.3.56*)
Miss B. Gurney (*from 1.9.56*)

Crop Protection

W. H. Read, M.Sc. (Birmingham), F.R.I.C.
R. J. Smith, B.Sc. (Lond.)
J. T. Hughes, B.Sc. (Lond.), A.R.I.C.
Miss V. A. Gentle, B.Sc. (Hull), (*appointed 1.9.56*)

Assistants (*Scientific*)

Miss J. Martin, Miss B. Hotston, Miss B. Finch

Non-Departmental

Director's Assistant and Photographer

J. E. Morton, A.R.P.S., F.R.M.S.
(*later in charge of Technical Services Unit*)

Assistant (*Scientific*)

Miss G. Marsh

Maintenance

R. Mingay

ADMINISTRATION

Secretary

J. Bishop, A.C.I.S. (*appointed 1.11.56*)

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Librarian/Assistant Secretary

Miss G. Dunster, B.A. (Lond.)

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Nursery Manager and Demonstrator

J. M. Evans, N.D.H.

Foreman

T. W. Syer

Assistants (*with more than one year's service at 31.12.56*)

F. Blake (28 years), R. Frost, L. Toms, P. Dawes, W. Hotston, Miss R. Mills, T. Gumbrill, Mrs. J. Hother, S. Barnett, G. Morrison, R. Brown, N. J. Jackson, Miss A. Rich.

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I. INTRODUCTION

The year has been largely one of settling in after the move from Cheshunt, with some continued development of the new site. To some extent it has also been a year of transition in that Dr. W. F. Bewley, who had guided the fortunes of the old Cheshunt station for so many years and who carried out the initial planning and development of the new Institute, retired during the course of it, his place being taken by Mr. F. W. Toovey. An appreciation of Dr. Bewley's services to the two research stations and to the glasshouse industry was published with the previous report.

A further change of some significance was the transfer to the Agricultural Research Council, as from 1st April, 1956, of responsibility for the administration of the Treasury grant made to the Institute to enable it to carry out its work. Before that date the Institute, and its forerunner, the Experimental and Research Station at Cheshunt, received its funds through the Ministry of Agriculture. In welcoming the closer association that will now develop with the Agricultural Research Council it is fitting to place on record our indebtedness to the Ministry for the very considerable help rendered over many years in the past and particularly during the initial stages of the development of the new Institute. Close contact will still be maintained with the Ministry in a number of ways, mainly through its Advisory Service.

It is regretted that this report is once again late in appearing, but the special circumstances of the transition period and the heavy work involved in building up the new Institute have inevitably occasioned some delay. It is hoped that our subscribers and others will show understanding of the situation and will be content to know that steps are being taken to publish the report more promptly in future. It is in fact hoped that the next Annual Report will appear shortly after this one.

Opening Ceremony

The official opening of the Institute was performed by His Grace, the Duke of Norfolk, K.G., G.C.V.O., on the 12th June, 1956. There were 242 guests at the ceremony, many of them from far and wide. After lunch served in a marquee erected in the grounds, the laboratories and glasshouses were thrown open to visitors and many availed themselves of the opportunity to see something of the Institute's work at first hand.

Governing Body

There were some changes in the Governing Body, four new members replacing those who did not seek re-election when their turn came to retire in October, 1955. The new members were Lt.-Col. L. R. Leach, Mr. Thos. Rochford, Mr. N. S. Liverman and Professor McGregor Skene.

Under its Chairman, Mr. T. Ainslie Robertson, the Governing Body consists of fourteen members. Of these, six are well-known growers chosen to represent the branch of horticulture which falls within the Institute's terms of reference. Six others are eminent scientists who, for the most part, hold, or have held, University chairs. The remaining member is a Senior Education and Advisory Officer of the Ministry of Agriculture, Fisheries and Food, Mr. C. E. Hudson, who brings a wealth of experience based on many years of advisory work and teaching. The Governing Body is thus a well balanced team with a wide knowledge of the problems of the industry the Institute has been set up to serve and of the contribution that science can make towards solving them.

The Governing Body held its Second Annual General Meeting on the 28th March, 1956. Two ordinary meetings for general business were held during the year, and a further meeting was held to appoint a Secretary to the Institute. The Executive Committee met twice to consider building projects and related matters, and the Research Committee met three times, once to consider the research programme for 1957, and on the other occasions to interview candidates for staff appointments.

Staff

Dr. W. F. Bewley, the Institute's first Director, retired at the end of September, 1956, after a lifetime of service to the glasshouse industry. He was succeeded by Mr. F. W. Toovey who had been appointed as Director-Designate from 1st January, 1956. During the period before assuming the full responsibilities of directorship the Director-Designate spent much time familiarising himself with the work of the Institute and with similar work in progress elsewhere. Visits were made to a number of research and experimental stations in England, and many useful contacts resulted. A short visit was also made to Holland to obtain an acquaintance with horticultural research and practice in that country, among the research centres visited being the Landbouwhogeschool at Wageningen and the Laboratorium voor Bloembollenonderzoek at Lisse. To obtain a broad picture of the industry served by the Institute and learn some of its problems, a number of glasshouse nurseries and mushroom farms in the Lea Valley, West Sussex, Lancashire and elsewhere were also visited by arrangement with local officers of the National Agricultural Advisory Service, whose very willing co-operation is gratefully acknowledged; on these occasions the very friendly and helpful reception of the growers concerned must be mentioned.

Mr. J. Bishop, A.C.I.S., was appointed Secretary to the Institute on the 1st November, 1956, and Miss G. Dunster then undertook the duties of Librarian and Assistant Secretary. Miss Dunster joined the old Cheshunt station in 1941, and our best wishes go with her in her new assignment.

Dr. N. W. Hussey was appointed as Senior Entomologist to fill the vacancy caused by Mr. Speyer's retirement, and he assumed duty on the 1st May, 1956. Miss C. D. Crocker, Experimental Officer, resigned her appointment in the Entomology Department on marriage and was replaced some time later by Miss B. Gurney, in the same grade, who had previously served as a Recorder.

A new post for bio-assay work in the Crop Protection Department was filled by the appointment of Miss V. A. Gentle, an entomologist, on the 1st September, 1956.

Mr. L. A. Darby's appointment as Plant Breeder, with the rank of Senior Scientific Officer, dated from the 1st December, 1955, but his name was inadvertently omitted from the staff list published in the previous report. Mr. Darby came to the Institute from the John Innes Horticultural Institution where he had been engaged on tomato breeding in the Department of Genetics under Dr. D. Lewis.

Mr. P. B. Flegg, who is engaged on mushroom research in the Chemistry Department, was promoted to Senior Scientific Officer with effect from the 1st October, 1956.

Mrs. J. D. E. Hack, Scientific Officer, resigned her temporary appointment in the Plant Pathology Department on the 30th September, 1956.

Three University students were given temporary employment during their summer vacation to enable them to obtain some experience of the Institute's work by assisting with the recording of the glasshouse experiments.

Internal Organisation

Late in the year a Technical Services Unit was set up under Mr. J. E. Morton, Senior Experimental Officer, who had previously served as Director's Assistant and Photographer. The function of the Unit is to assist the research departments in the fabrication of experimental equipment and apparatus and to provide a photographic service. It has been found to meet a very real need.

Capital Developments

Plans for new glasshouses, with ancillary buildings, to meet the special requirements of the research departments were completed, and tenders were received mid-way through the year. After

consideration by the Executive Committee in July, 1956, an application was made to the Agricultural Research Council for a capital grant to finance the work and notification that this was approved was received in October, 1956. Building operations commenced straightaway and good progress had been made by the end of the year.

The new special purpose glasshouses, as they are called, consist of four separate units for the Plant Physiology, Plant Pathology, Chemistry and Crop Protection Departments respectively. All are of metal-framed construction and it is hoped that this will considerably reduce future maintenance costs. All units have small field laboratories attached to them, and in the case of the Plant Physiology glasshouse these are partly sunken in the ground in order to maintain an even temperature for the delicate recording equipment to be housed in them. The Plant Physiology glasshouse is of quite special design; it is almost square in floor area and is of an unusual height, being 12ft. to the eaves and 25ft. to the ridge, the object being to provide the most uniform possible growing conditions under which plants of indeterminate habit, such as the tomato, can be grown throughout the season without interruption to their growth by stopping, etc. The houses for the other three departments are of a standard commercial type but have been compartmented to meet the special needs of those departments. A potting shed and sterilizing unit is being built to serve all the new experimental glasshouses, and a new steam boiler is to be installed. The latter is of the "Steambloc" packaged type, of 2,250,000 B.T.U. capacity, and is fitted with fully automatic oil-firing equipment. It will serve not only the new experimental glasshouses but also the mushroom research unit to be erected in due course, and it has a large reserve capacity to cover future developments.

Plans for an administrative building and for the mushroom research unit were well advanced by the end of the year, but the indications were that in the difficult financial situation prevailing it might be some time before these could be proceeded with.

Trial Glasshouses

The Institute has at present just over $1\frac{1}{4}$ acres of glass plus three 100ft. propagating houses. The growing houses, arranged in seven separate blocks, are of standard commercial types and have a traditional heating system based on 4in. pipes, although the circulation of the water in them is assisted by means of a pump. These houses provide a valuable adjunct to the research programme and must therefore meet the exacting requirements of a research station. They are now referred to as "trial" glasshouses and it is perhaps necessary to explain their function in relation to the "special purpose" glasshouses of the research departments. The latter provide facilities for the initial stage of research, much of which will be carried out with plants in pots; this work calls for the greatest precision in experimental procedure, of course. The results obtained at this stage will then need to be tested on a larger scale, a scale nearer that of commercial practice, and this will be carried out in the trial glasshouses. Many experiments, e.g., nutritional trials, plant breeding trials, can in any case only be satisfactorily undertaken in fairly large scale border experiments, and the trial glasshouses have to serve for these experiments as well. After sufficiently extensive trial at the Institute the next stage might be for the more important findings to be tested under different conditions throughout the country, and here it is hoped to enlist the co-operation of the National Agricultural Advisory Service whose Experimental Horticulture Stations have been established at suitable centres for just this purpose.

While it is important that the large scale trials referred to should be carried out under conditions as closely related to those of normal commercial practice as possible, the requirements of accurate experimentation are paramount. The limitations of space in a glasshouse are such that in order to achieve a reasonable degree of precision in experimental work everything possible must be done to eliminate man-made variations. This means the most careful control of the growing

conditions, particularly temperature, so that the exact conditions the research worker requires for his experiments are actually obtained. The whole trend in glasshouse experimental work at the present time is in fact towards achieving better and better control of these conditions.

The performance of the trial glasshouses has been viewed from this angle and it has become evident from experience during 1956 and earlier that they are not providing a sufficiently uniform environment in which to carry out experiments of the accuracy demanded by present-day research standards. It is believed that measures can be taken to improve the uniformity, particularly as regards temperature control, and discussions to this end were initiated with the National Institute of Agricultural Engineering towards the end of the year.

Experiments in the Trial Glasshouses, 1956

During 1956 some of the trial glasshouses were allocated to the research departments and the work carried out in them will be found described in the sections of this report relating to those departments. Other experiments are described in the following paragraphs.

Calibration of Block B

Calibration of the block of four aeroplane houses, B1—4, was continued, and the chemists again took soil samples for analysis. Results of the analyses of the tissue samples taken in the previous year in this and the neighbouring block C1—4, are given in the report of the Chemistry Department. The object of the calibration is to determine the yield differences that occur in various parts of the block when cropped uniformly with tomatoes, and the analyses are being carried out to see whether these differences can be related to the composition of the soil or to certain chemical constituents of the plants. When the yield differences have been analysed statistically it will be possible to decide the best size of plot for future experimental work in this block, and the observed yield differences from one part of the block to another may provide a useful guide to the layout of experiments.

The essence of a calibration trial such as this is that the whole area should be treated as uniformly as possible, leaving the expected yield differences to arise solely from variations in the soil and from environmental variations within the block. In the present case it was also desired to maintain only the minimum level of fertility necessary to ensure a reasonable crop in order not to prejudice the use of the block for future experiments on soil nutrition. Preliminary manuring was therefore limited to a light dressing of horse manure, at the rate of 30 tons to the acre in 1956, and no base fertilizer was applied. Some top dressing was given during the course of the crop. The whole block was again planted with the variety E.S.5, on 23rd/24th February, 1956. For the purpose of recording each house in the block was marked out into 56 plots as in the previous year, all plots consisting of 8 plants. The crop from each plot was harvested and weighed separately, and the total yields, expressed as pounds per plant, are given in Table I.

Owing to the restricted manuring growth was very uneven, and it was evident that many of the plants were showing marked nutrient deficiency. This, it is feared, may have introduced an unexpected cause of variability into the trial. The average yield from the whole block was 38.8 tons to the acre.

Fertilizer experiments on tomatoes in Block C

Calibration of Block C was discontinued in 1956, and two of the houses were allocated to the Plant Physiology Department for work on soil moisture tension and transpiration which is briefly mentioned in the report of that department. The remaining two houses, C3 and C4, were laid down to fertilizer experiments.

TABLE I

Calibration of Block B

Average yield per plant per plot, 1956

Plot	House				Plot	House			
	1	2	3	4		1	2	3	4
	lb.	*lb.*	*lb.*	*lb.*		*lb.*	*lb.*	*lb.*	*lb.*
1	8.1	3.5	8.6	7.7	29	10.0	9.5	9.3	7.7
2	6.4	4.4	5.7	7.4	30	8.1	7.9	8.3	6.4
3	7.7	7.4	5.6	7.7	31	8.2	5.8	7.7	6.7
4	7.8	6.6	5.2	7.7	32	9.0	5.9	8.2	7.3
5	6.9	6.6	4.8	8.2	33	8.0	7.6	7.9	8.2
6	7.0	5.9	5.7	6.9	34	6.9	7.8	8.1	7.0
7	3.1	6.8	5.9	6.1	35	7.9	8.2	6.4	7.6
8	4.0	6.5	5.1	6.1	36	7.6	8.6	8.0	6.6
9	4.2	6.5	4.8	7.3	37	5.6	8.9	8.3	3.7
10	5.8	6.7	5.2	5.6	38	5.5	7.4	7.9	5.5
11	7.9	6.7	6.7	8.1	39	8.0	7.4	7.5	6.9
12	8.2	7.7	6.8	7.5	40	5.8	6.8	6.9	7.7
13	7.6	6.2	5.9	8.1	41	8.1	7.3	5.2	8.0
14	8.5	6.9	5.3	8.2	42	7.0	6.3	6.5	2.7
15	7.2	7.2	7.1	5.6	43	6.6	5.8	7.9	5.2
16	8.4	5.4	7.3	8.0	44	5.6	5.9	6.3	5.7
17	8.6	7.0	7.8	6.3	45	5.2	7.1	7.0	6.3
18	9.6	5.9	7.6	8.1	46	6.3	7.5	7.4	7.4
19	6.8	6.5	7.2	6.4	47	6.4	7.2	6.1	6.3
20	8.0	6.3	7.8	7.2	48	6.8	8.3	7.9	7.6
21	7.3	6.8	8.1	6.7	49	6.9	6.8	7.2	4.3
22	8.7	6.1	6.7	7.3	50	7.2	6.8	6.9	2.4
23	8.2	7.7	6.4	8.2	51	6.9	5.6	6.3	3.3
24	3.5	6.9	7.8	6.7	52	7.8	5.6	7.1	7.2
25	7.7	8.3	6.9	8.1	53	6.1	6.1	5.9	7.7
26	8.6	6.9	8.2	7.5	54	9.0	6.8	5.3	6.5
27	8.6	6.6	7.5	6.4	55	5.7	7.4	5.0	7.6
28	10.2	10.2	7.4	8.9	56	6.4	5.5	1.9	6.0

In C3 the experiment was one designed to test the effect of four *levels of base fertilizer* mixture on tomatoes, the treatments being as follows:

A. 4 oz. each of hoof and horn, bone meal and sulphate of potash per square yard.
B. 2 oz. ,, ,, ,, ,, ,, ,, ,, ,, ,,
C. 1 oz. ,, ,, ,, ,, ,, ,, ,, ,, ,,
D. No base dressing.

This experiment arose out of observations made during the previous year when the appearance of the plants in certain other houses on the nursery led to the suggestion that in some instances they might have been over-fed, the plants near the paths, with only additional supplies of stable manure to draw upon and no top dressing, growing as well as or better than other plants given normal base and regular top dressings. It was therefore decided to test the relative merits of different levels of base dressing applied to a soil of low nutrient status, treatment A being equivalent to normal commercial practice.

The experiment was designed as four randomized blocks of the four treatments, with three double rows across the border in each plot. Only the four middle rows in a plot were recorded, the two outer rows being regarded as discards. Asbestos sheets were used to separate the plots and prevent wash, and there were two double guard rows at each end of the house.

The variety E.S.5 was planted on 4th March, 1956, at a spacing equivalent to 12,185 plants per acre. The soil was manured with 20 tons of stable manure before planting, and base dressings were given according to the experimental treatments. Top dressings of a proprietary NPK mixture were given every ten days from 3rd May to 14th September, the same rate of dressing being given to each treatment.

Within two weeks of planting out a very marked response to the different levels of base fertilizer was apparent. Plants receiving the highest level of fertilizer were growing well, whereas those receiving no base fertilizer showed a dull grey-green colour in the foliage with purple pigmentation of stems and midribs. The difference between the treatments decreased subsequently, however, particularly when application of overall top dressings was commenced. The average yield throughout the whole experiment, which occupied 1/27th acre of glass, was 41 tons per acre, 63% of the fruit being in the pink, pink and white, and white grades. The average yields for the various base dressing treatments were as follows:

A.	4 oz./sq. yd. (hoof & horn, bone meal & sulphate of potash)	45.1 tons/acre
B.	2 oz./sq. yd. (,, ,, ,, ,, ,, ,,)	40.9 ,, ,,
C.	1 oz./sq. yd. (,, ,, ,, ,, ,, ,,)	38.5 ,, ,,
D.	Nil	41.8 ,, ,,

Statistical analysis showed no significant difference in crop yields up to the end of June, but cumulative totals up to the end of July, August and September showed, in each case, significantly higher yields ($P = 0.05$) from plots receiving the highest application of base fertilizer. Differences in total yield for the whole season, including fruit picked green when the plants were pulled out, just failed to achieve statistical significance at $P = 0.05$ (F test: required, 3.86, found 3.61).

The house C4 was devoted to a *top dressing experiment*, the treatments being as follows:

A.	Organic fertilizer at 2 oz. per square yard
B.	,, ,, $\frac{2}{3}$ oz. ,, ,,
C.	Inorganic fertilizer at 2 oz. ,, ,,
D.	,, ,, $\frac{2}{3}$ oz. ,, ,,

The organic mixture consisted of one part each of nitrate of potash and sulphate of ammonia, one and a half parts each of triple superphosphate and ordinary superphosphate, and five parts of dried blood, its total composition being N 9.95%, P_2O_5 9.00% and K_2O 4.4%. The inorganic mixture consisted of one part of nitrate of potash, four parts of sulphate of ammonia, four and a half parts of ordinary superphosphate and half a part of triple superphosphate, its total composition being N 9.75%, P_2O_5 9.00% and K_2O 4.4%.

The experiment was designed as four randomized blocks of the four treatments, with each plot consisting of two double rows across the border. There were shared guard rows of one double row between plots, with additional guard rows at the ends of the houses.

The variety E.S.1 was planted in fibre pots on 7th March, 1956, at a spacing equivalent to 12,185 plants per acre. In preparing the soil 20 tons of stable manure per acre and half the usual base dressing were dug in before planting. Three top dressings, according to the treatments laid

down, were applied throughout the growth of the crop. The overall average yield, for 1/27th acre of glass, was 43.2 tons per acre, with 65% of the fruit being in the pink, pink and white, and white grades. The average yields for the experimental treatments were as follows:

A.	Organic at 2 oz./sq. yd.	44.3 tons/acre
B.	,, $\frac{2}{3}$,, ,,	41.9 ,,
C.	Inorganic at 2 oz./sq. yd.	44.6 ,,
D.	,, $\frac{2}{3}$,, ,,	42.4 ,,

Spacing experiment on tomatoes in Block D

In Block D, houses D2 and D3 were allocated to the Chemistry and Plant Physiology Departments respectively for tomato experiments which are fully described in the reports of those departments. The other two houses, D1 and D4, were laid down to a *tomato spacing experiment* which was a repetition of that carried out in houses D1 and D2 in 1955 (see page 29 of 1954/55 Annual Report). On this occasion, however, both houses were planted with the variety Potentate. The treatments were exactly the same as in the previous year but are repeated here for ease of reference:

A. About 16,000 plants per acre—normal spacing.
B. ,, 8,000 ,, ,, ,, —half spacing.
C. ,, 24,000 ,, ,, ,, —dense spacing.
D. As A, but alternate plants stopped at fifth truss and all side shoots removed, these plants being taken out immediately the crop was picked.
E. As D, but a shoot from an adjacent plant trained into the vacant space above the "stopped" plants.

The experiment was laid down in randomized blocks, with four replications of the five treatments in each house. Each plot consisted of two double rows across a border; there were no guard rows between plots, but there were four double rows as guards at the north end of each house and five at the south end. The randomization in D1 was the same as that adopted in both D1 and D2 in the previous year, but in D4 the treatments were randomized in a different manner.

House D1 was planted on 2nd March, but D4 was planted nearly a month later, on 28th March. In both houses stable manure at the rate of 20 tons per acre was dug in before planting and a normal base dressing of 4 oz. of mixed fertilizer per square yard was applied.

The average yields for the various treatments were as follows:

	Treatment	*House* D1	*House* D4
A.	16,000 plants/acre	77.5 tons/acre	59.8 tons/acre
B.	8,000 ,, ,,	57.6 ,, ,,	45.3 ,, ,,
C.	24,000 ,, ,,	81.1 ,, ,,	65.1 ,, ,,
D.	As A, but half stopped at 5th truss and removed	68.8 tons/acre	55.2 tons/acre
E.	As D, but shoot trained across from adjacent plants	72.4 ,, ,,	59.5 ,, ,,

The results show the same trends in the two houses and are roughly parallel to those obtained in the previous year; once again, the serious reduction in yield from reducing the plant density to 8,000 per acre is evident. It is interesting that the proportion of fruit in the pink, pink and white, and white grades for each treatment showed very much the same trends as the yields.

Tomato variety trial in Block F

In F1 and F2, one of the blocks of houses presented to the Institute by the Tomato and Cucumber Marketing Board, a *tomato hybrids and varieties trial* was carried out. Twenty-four genotypes were incorporated in the trial, seven of them being commonly grown varieties and the remainder various hybrids. The trial was laid out in four randomized blocks, each block being allotted to the border on one side of a house. The randomization was arranged by the Plant Breeder, Mr. Darby, but he was not otherwise responsible for the trial. Each plot consisted of 20 plants, and guard rows were planted at the north and south ends of each house. The trial was planted on the 13th January, 1956.

The houses were prepared by incorporating stable manure at the rate of 30 tons per acre, and a base dressing of sulphate of potash and superphosphate was applied before planting. The plants were planted in fibre pots which were set out at a spacing equivalent to about 16,000 plants per acre. The crop was rooted out at the end of July. The yields obtained to that date are given in Table II which also includes data on grading and on the proportion of blotchy fruit.

TABLE II

Tomato Varieties and Hybrids Trial 1956 (Houses F1—2)

Crop yields and fruit grading

Variety or Hybrid	Crop yield per plant						Total yield per acre	Fruit grading		
	April	May	June	July	Green fruit	Total		Blotchy	Pink and Pink & White	White
	lb.	*lb.*	*lb.*	*lb.*	*lb.*	*lb.*	*tons*	%	%	%
1. Delicious	0.1	0.7	2.5	1.6	0.4	5.3	37.8	6.9	45.7	27.7
2. Down's Seedling	—	0.7	2.7	2.2	0.6	6.2	43.5	7.0	50.0	30.7
3. E.S.5.	—	0.9	3.1	2.1	0.4	6.5	46.2	4.1	54.2	25.2
4. Kondine	—	0.7	2.6	2.5	0.3	6.1	43.7	4.4	39.5	38.1
5. Potentate	—	1.1	2.3	1.5	0.6	5.5	39.1	4.6	35.5	20.2
6. Potential	—	0.8	2.4	2.3	0.5	6.0	43.1	5.1	55.0	23.0
7. Up-to-date	—	0.7	1.8	1.6	0.6	4.7	33.8	7.5	17.3	13.7
8. Potentate × E.S.5	—	1.5	2.3	1.6	0.5	5.9	42.2	2.6	48.5	25.5
9. Potentate × Potential	—	1.3	2.5	1.7	0.6	6.1	43.4	5.0	51.4	15.8
10. E.S.5 × Potentate	—	1.2	2.4	1.5	0.5	5.6	40.4	4.0	48.5	22.9
11. Potential × Potentate	—	1.2	2.5	1.6	0.5	5.8	41.1	5.5	46.1	18.9
12. Delicious × Potentate	0.1	1.7	1.9	1.2	0.3	5.2	37.0	4.3	44.6	22.6
13. Kondine × Potentate(F_1) × Potentate	0.1	1.2	2.0	1.3	0.4	5.0	35.8	4.8	33.8	13.6
14. Potentate × Kondine (F_2) × Potentate	—	1.5	2.3	1.3	0.5	5.6	39.8	4.9	35.8	14.4
15. Delicious × Potentate (F_2) × Potentate	0.1	1.6	2.3	1.6	0.6	6.2	44.2	5.1	38.7	14.0
16. Potential × Potentate (F_3) × Potentate	—	0.9	2.6	2.0	0.6	6.1	43.5	5.5	45.8	17.8
17. Potential × Potentate (F_2) × Potential	—	0.9	2.4	1.9	0.5	5.7	40.4	3.2	53.2	28.5
18. Potentate × Down's Seedling	0.1	1.5	2.0	1.5	0.5	5.6	39.6	4.2	41.6	29.7
19. E.S.5 × Potential	—	1.2	2.6	1.9	0.5	6.2	44.4	3.4	55.7	25.2
20. Potentate × Delicious	—	1.4	2.3	1.6	0.4	5.7	40.5	4.8	45.5	45.2
21. Potential × E.S.5	—	1.0	2.4	2.1	0.6	6.1	43.6	3.9	51.4	27.6
22. Up-to-date × Potentate	0.1	1.4	2.2	1.6	0.7	6.0	42.7	5.8	26.0	14.1
23. Potentate × Up-to-date	0.1	1.5	2.2	1.5	0.6	5.9	41.9	6.7	24.3	13.2
24. Down's Seedling × Potentate	—	1.7	2.4	1.6	0.6	6.3	45.0	4.7	45.4	25.5

Reserve Land

The Institute's reserve land comprises 52 acres arable and about 30 acres of grazing, the latter being north of the railway line. The arable land was sown to winter wheat and oats in the autumn of 1954 and the crops harvested in 1955 gave satisfactory yields. In 1956, a crop of spring-sown oats, variety S.225, was taken, the average yield being 1 ton $2\frac{3}{4}$ cwts. per acre. The crop was short in the straw, and rather weedy, which factors, in conjunction with the poor season, no doubt contributed to the rather low yield.

The farming policy to be adopted for the arable land was reviewed by the Governing Body after consultation with the local N.A.A.S. County Agricultural Officer, and it was decided that after a further crop of spring sown corn, probably barley, the land should be laid down to a short ley of grass and clover, followed by a bastard fallow. The rotation started with the sowing of winter corn in 1954 would then be repeated. The main objects of this policy are (i) to maintain, or if possible, improve soil fertility, and (ii) to cover costs and obtain the best possible financial return. As farming of this land is quite subsidiary to the main work of the Institute it is also important that the rotation to be followed should be relatively simple to carry out and not draw too heavily on the available resources of staff and equipment.

The arable land forms a valuable reserve for the Institute's future developments, including the erection of new glasshouses, the re-soiling of old houses, and the laying out of plots for its work on outdoor flowers and shrubs. It is therefore imperative that the land should be kept in good heart and it is hoped that the farming policy decided upon will achieve this.

Miscellaneous

Staff Association

A Staff Association has been formed to look after the welfare and professional interests of the staff and to promote social and cultural activities. It is representative of all grades of staff, including workers on the nursery.

Liaison

A strong liaison has been forged with the National Agricultural Advisory Service, which is the first line of contact with the grower. The Director serves on the N.A.A.S. Flowers and Glasshouse Groups and attends meetings of the corresponding Working Parties of the Agricultural Improvement Council. He is also a member of the Station Advisory Committees of the N.A.A.S. Experimental Horticulture Stations at Efford in Hampshire, Hoddesdon in the Lea Valley, Fairfield in Lancashire, and at Cawood in Yorkshire, and in this way is able to keep in close touch with the work of these stations where so many experiments of importance to growers of glasshouse and flower crops are carried out.

The County Horticultural Officer for West Sussex, Mr. E. R. Keighley, is a frequent and welcome visitor to the Institute, and some of his colleagues in the Advisory Service also pay visits from time to time.

Dr. Winsor, Head of the Chemistry Department, has been invited to serve on the Bulbs Advisory Panel of the Kirton Experimental Husbandry Farm in Lincolnshire.

The Director is a member of Sub-Committee W/G, Horticultural Applications, of the Electrical Research Association's Committee which deals with Rural Electrification, and this provides contact with the work that is being done at the Association's Field Station at Shinfield Green, near Reading, where many experiments of horticultural interest are carried out.

Conferences

Members of the staff took part in a number of outside conferences during the year. The Director-Designate attended the Third Conference on Management and Organisation for Senior Scientists and Members of the Works Group and Related Classes held at Peterhouse, Cambridge, from 20th to 27th July, 1956. He also attended the Third Easter School in Agricultural Science held at the University of Nottingham, Sutton Bonington, when the subject was "The Growth of Leaves"; at this conference the Institute was also represented by Dr. A. J. Cooper.

Mr. P. B. Flegg represented the Institute at the Third International Conference on Mushroom Science held in Paris on 14th—23rd June, 1956, and Mr. L. A. Darby attended the A. R. C. Plant Breeders' Conference which was held at the Plant Breeding Institute in Cambridge on 4th and 5th July, 1956.

In November, 1956, a strong team from the Institute took part in the A.R.C's conference which was convened to discuss the problem of *Didymella* Stem Rot of the tomato. The suggestion that such a conference should be held was made during a meeting of the Institute's Research Committee some time earlier.

The Institute was also well represented at the Mushroom Growers' Association's Exhibition and Conference which was held at Eastbourne on the 14th and 15th November, 1956. The Director addressed the Conference on the progress and future programme of mushroom research at the Institute.

Shows

The Institute staged an exhibit in the Scientific Section at the Chelsea Flower Show in May, 1956. The stand showed the present stage in the Institute's development and illustrated some of the current work on plant diseases.

A stand showing some aspects of the Institute's work for the mushroom industry was set up at the Mushroom Growers' Association's Exhibition at Eastbourne in November, 1956, and attracted a good deal of interest.

Talks to Growers

By arrangement with the N.A.A.S., Dr. A. J. Cooper gave a talk on "Blotchy Ripening of Tomatoes" to a group of growers at Norwich in February, 1956.

Visits

Visits undertaken by the Director-Designate and by members of the staff attending conferences have been mentioned above. Other places visited at various times included the Fernhurst Research Station of Messrs. Plant Protection Ltd., and several commercial nurseries and mushroom farms in West Sussex and elsewhere. These visits serve to broaden the Institute's contact with the industry and with workers in similar fields at other stations.

Visitors

A considerable number of visitors were received at the Institute during the course of the year, some of them from overseas. The Institute was particularly honoured by a visit from Their Graces, the Duke and Duchess of Norfolk and their daughters on the 21st August, 1956. The Duke had previously performed the official opening ceremony, as already related. Among organized groups

to visit the Institute were the Nazeing and District Growers' Discussion Group, the Rochford Hundred Horticultural Discussion Group, a party of students from Reading University, two parties of local schoolgirls, and the St. James (Littlehampton) Men's Fellowship.

Honours and Awards

It is a great pleasure to record the award of the C.B.E. to Mr. C. E. Hudson in the New Year's Honours List. Mr. Hudson has served on the Governing Body since the beginning.

SUMMARY OF RESEARCH

The Institute has been set up to conduct research on problems in the cultivation of glasshouse crops and mushrooms, and of bulbs, flowers and shrubs grown in the open. This is a very wide field, and with the staff and facilities available at present it is only possible to tackle some of the problems of a few of the more important glasshouse vegetables and flowers and of mushrooms. These crops form a section of horticultural industry worth many millions of pounds annually and there are many problems in their cultivation still urgently awaiting a solution. Until an adequate level of research effort can be applied to these problems, which is by no means always the case at present, it would be unwise to spread our activities over a wider field. Research conducted on too broad a front leads to no worth-while advance within a measurable time, and at the Glasshouse Crops Research Institute we have to strike a balance between covering too wide a field and working on so few crops that growers will feel that the Institute is not really living up to its name. Nevertheless we are constantly alive to our wider responsibilities and are preparing for the day when it will be possible to extend our work to many more crops. Through the Director's attendance at meetings of committees dealing with experiments on flowers and bulbs the Institute is kept informed of problems affecting those crops, and the invitation to Dr. Winsor to serve on the Bulbs Advisory Panel at the Kirton Experimental Husbandry Farm means that the Institute is able to keep in close touch with the experiments on bulbs in progress at that station.

As mentioned in the previous report the Institute has assumed responsibility for mushroom research which has been transferred to it from the former Mushroom Research Station at Yaxley, near Peterborough. Research on the crop got well under way during the year, being facilitated by the provision of a shed in which mushrooms can be grown under conditions similar to those of commercial practice. This shed was the one previously in use at Cheshunt, and it was moved to the Institute as a temporary measure while the new mushroom research buildings were being planned.

Organization

The departmental organization evolved at Cheshunt has been continued at the Institute but the appointment of a Plant Breeder has made it possible to extend work in the field of crop improvement. So far breeding work has been limited to the tomato and cucumber, but towards the end of the year preparations were made for initiating work on lettuce.

Mushroom research has been integrated with the rest of the work of the Institute, and cultural questions are at present dealt with by the Chemistry Department and disease problems by the Plant Pathology Department, the three members of the Yaxley staff who transferred to the Institute (Mr. Flegg and his assistant, Miss Warman, and Miss Gandy) being posted to these two departments. Research on mushroom pests has been started by the Entomology Department.

PLANT PHYSIOLOGY

Under Dr. E. R. Leonard the work of the Plant Physiology Department is at present confined to the major glasshouse crop, the tomato, and, for the most part, with the variety Potentate, the one most widely grown.

Growth of the Tomato Plant

As a first step towards the solution of more practical problems a complete growth analysis of the various organs of the plant after planting out in the border is being undertaken, and a large volume of data was accumulated from the observations made during the year. These observations, carried out on a limited number of plants, concluded the first stage of the growth analysis work, which has been in progress for three years. The complete analysis of the data will take a considerable time, but preliminary treatment has disclosed very interesting growth patterns which are full of practical significance. Probably the most important finding is the check to the steadily increasing rate of development of the roots, shoots and leaves which occurs approximately early in May and which appears to be quite independent of the age of the plant or of its cultural management. A similar check in the rate of development of the fruit occurs a few weeks later.

Following up the growth analysis work the first half of a trial was laid down in 1956 in a vinery type glasshouse to test a possible commercial application of the two most important facts which have emerged from this work. These relate to the regularly recurring pattern of growth of the side shoots up the stem of the tomato, the more vigorous side shoots bearing roughly the same amount of fruit as the main stem, and the check in growth of the main stem and side shoots which, as already mentioned, has been found to occur each year in early May. Three methods of pruning, in which different numbers of side shoots were retained, were compared with the standard method in which all side shoots are removed. It was found that the retention of selected side shoots led to a greater total yield per plant and improved quality of fruit, but it must be emphasized that this result is from one experiment in one year and relates to a single variety. Although the total yield was increased there was a decrease in early yield, and some attempt was made to assess the economic importance of this.

Blotchy Ripening of the Tomato and Allied Disorders

During the course of the growth analysis work on the tomato a considerable volume of data on the incidence of abnormal ripening has been accumulated. The type of abnormality that is of most concern to growers is that rather loosely described as "blotchy ripening", and there is reason to believe that this disorder loses the industry something like a quarter of a million pounds annually. The Plant Physiology Department is not at present working on the blotchy ripening problem as a specific project but has been led to give a good deal of attention to it as a result of the information on fruit ripening collected from the growth analysis studies. (The Chemistry Department is also making an approach to the problem from the analytical angle, as will be described later). A thorough search of the literature on blotchy ripening and allied disorders has been made anda critical review of it has been written by Dr. A. J. Cooper. This has disclosed a very confused state of knowledge on the subject of these disorders, and it is clear there are a number of commonly-held misconceptions as to their cause. For this reason it has been decided to include the review in this Annual Report. It will be seen that from the published literature the dominant factors determining the occurrence of blotchy ripening are season and, to a lesser extent, variety. The evidence on the role of plant nutrition is conflicting, but it is certain that it is overridden by the seasonal effect. Which factor associated with season is the important one has not yet been determined, but it is hoped that the plant physiological studies in progress will shed light on this.

The literature review shows that the definition of the term "blotchy ripening" as used by various writers is vague and uncertain; there are also some features of the disorder which are in dispute. Accordingly an attempt has been made to define more precisely the abnormalities that occur, and a tentative classification of pigmentation abnormalities has been drawn up. It is hoped to publish the detailed scheme elsewhere, but a simplified scheme has been used for the recording

of the fruit harvested in the plant physiological studies and is outlined in a further paper by Dr. Cooper in this report. This is given as an introduction to an account of observations on the incidence of the more important pigmentation grades on a number of carefully recorded plants during 1956. These observations showed the value of the proposed fruit grading scheme, and its use in 1956 demonstrated that in that year there appeared to be marked seasonal differences between two of the grades of green mal-pigmentation, which together contained the majority of the non-uniformly coloured fruit.

It must be emphasized that these studies on blotchy ripening and allied fruit ripening problems are of a very preliminary nature only, but they are paving the way for precise experiments on the cause of the disorders which it is hoped to undertake in due course.

Studies on Soil Moisture in the Glasshouse

Factors of the glasshouse environment, in particular, soil moisture tension, are also being studied by the Plant Physiology Department, both in the border and in pots. In this work two varieties of tomato, Ailsa Craig and Potentate, were grown in isolation and, in the case of the latter, at two feet square spacing, and soil tensiometers of a laboratory type were arranged to investigate the distribution of soil moisture tension during the growing season. A preliminary investigation on soil moisture tension and soil water loss in relation to tensiometer sensitivity and to environmental measurements was also undertaken using potted tomato plants and a large capacity balance of very high sensitivity. Both indicating and null-recording tensiometers were used in this work.

CHEMISTRY

The work of the Chemistry Department, under Dr. G. W. Winsor, consists of studies in plant nutrition, soils and fertilizers. Cultural problems of the mushroom are also studied, particular attention being paid to certain aspects of the casing layer.

Composition of the Tomato Fruit

The investigation of the composition of the tomato fruit has continued and has given a bio-chemical turn to the work of the department. The investigation is being undertaken in relation to variety and state of ripeness of the fruit, and has particular reference to problems of fruit quality and ripening disorders.

Analyses of the sap expressed from fruit picked from the Plant Breeder's trials have shown interesting differences between varieties. Two varieties in an early planting, Delicious and Up-to-date, gave particularly high values for dry matter, total solids, reducing sugars, acidity and nitrogen content, while Down's Seedling and Potential gave relatively low values for these constituents. In a later planting Vagabond showed the highest values for dry matter, total solids and sugars, whereas Baby Lea gave the lowest values for these constituents. Three strains of Potentate planted in this trial showed considerable similarity in the analytical results, although there were significant differences in titratable acidity.

The authors of the paper reporting these results point out that it is rather surprising that the composition of glasshouse tomatoes has not received greater attention, and they go on to suggest that the sugar or acid content of a tomato is basically a more important characteristic than are minor irregularities in shape or even in pigmentation. Little is known of the extent to which the flavour of tomato fruit is related to its chemical composition, and, in any case, present grading systems do not take flavour into account, although there appears to be some interest developing in this question. The analytical work undertaken at the Institute represents a preliminary stage in a

thorough investigation of the composition of the tomato fruit and is of obvious importance in relation to problems of fruit quality, which, in the future, may perhaps include questions of flavour. It is fully realized that such analytical tests as have been used so far are hardly adaptable to routine commercial grading, but the introduction, where possible, of relatively rapid physical techniques of measurement is a possibility that is receiving attention.

Continuing the study of the changes in the composition of the sap of tomato fruit during ripening more extensive analyses of sap from fruit of the variety Potentate were made during 1956. A selection of the results is given in this report and will be found to show a number of features of interest. The results are for sap expressed from whole fruits or from fruit walls, or for the free juices in the fruit, and they are based on fruit at various stages of ripeness. The original object in studying changes in the composition of the sap during ripening was to relate such changes to the differences observed between normal and blotchy fruit. In previous work it was found that normal fruit showed higher values for dry matter in the fruit, and for total solids, sugar, nitrogen and acidity in the sap. Similar results were obtained in 1956, and, in addition, significantly higher values for potash and ash, and somewhat higher values for electrical conductivity, were found in the sap of normal fruit, as compared with the sap of blotchy fruit. Comparing these results with those obtained from the studies on the changes during ripening it seems doubtful whether the differences between normal and blotchy fruit can be ascribed to delayed ripening in parts of fruit affected by "blotchiness".

The composition of "waxy" fruit, that is, fruit showing waxy or translucent areas in the outer walls, has also been studied, and it has been found that, in general, the content of total solids, sugars, nitrogenous compounds and acids in the expressed sap, already found to be lower in blotchy than in normal fruit, is even lower in "waxy" fruit. The possibility that waxy patch is a more severe form of blotchy ripening is therefore not inconsistent with these results.

A new development, reported in a brief note by Dr. J. N. Davies, is an examination of some of the organic constituents of tomato fruit, using chromatographic methods. The carbohydrates have been selected for initial study. Among sugars found in expressed sap or in alcohol extracts, substances indistinguishable chromatographically from fructose and glucose have been common, and an attempt is being made to determine them quantitatively.

The Composition of Tomato Foliage and its Relation to Crop Yields

The calibration of two blocks of trial glasshouses, B1—4 and C1—4, has been referred to in an earlier part of this Introduction. The chemists have undertaken a considerable amount of sampling and analytical work in connection with these uniformity trials, and the results for soil samples taken in 1954 were reported last year and discussed in relation to crop yields. ("Uniformity trials in tomato houses B1—4, C1—4", by G. W. Winsor and J. N. Davies. *Rep. Glasshouse Crops Res. Inst. 1954/55*, pp. 84-7). Leaf samples taken during 1955 were analysed during 1956, and the results are given in the present report. The values for nitrogen, phosphate, and potash in the leaves all showed considerable variability, those for potash being extremely low throughout while those for nitrogen were below average. Somewhat surprisingly the values for phosphate were in many cases somewhat higher than is normally encountered, although the level of available phosphate in the soil is very low. The phosphate level is so low, in fact, that it has a marked effect on growth, particularly in the early stages, and this effect is distributed very unevenly over the site.

Particular interest attaches to the relation between crop yields and the composition of the foliage, and this has been studied statistically. Taking the eight houses, comprising the two blocks, as a whole, there was a highly significant positive correlation between yield and the amount of

nitrogen, phosphorus and potassium in the leaves, but when the results for the separate houses or separate blocks were considered the correlations were often found to be non-significant or, in some cases, reversed. The most consistent story was found with potassium, where five out of eight houses showed significant positive correlations between crop yield and potassium content, generally accompanied by significant negative correlations between yield and phosphorus content. The phosphorus story was very confused, and it is believed that the relatively high values obtained may have been due to the accumulation of phosphorus in the leaves where growth and cropping were retarded by other factors. Generally, there was a negative correlation between yield and phosphorus content of the leaves, but this is most unlikely to have given a true picture, as subsequent experience suggests that phosphorus deficiency may well have been a limiting factor in the early stages of growth.

Studies of this nature are of the greatest interest in connection with the nutrition of the tomato plant, but their value would be increased if a complete nutrient uptake picture could be obtained from samples, both of leaves and fruit, taken throughout the growth of the crop and studied in relation to the nutrient status of the soil. Unfortunately this would involve the Chemistry Department in far more analytical work than it could possibly undertake with the staff and facilities at its disposal at present. Nutrient uptake studies are however contemplated in connection with a long term nutrition experiment to be laid down in one of the blocks of glasshouses, Block B, which has been the subject of calibration.

Urea-formaldehyde Compounds as Nitrogenous Fertilizers

The work on urea-formaldehyde compounds, which was started in 1950, has been continued. The objectives behind this work were set out in the Annual Report for that year ("Urea-formaldehyde reaction products as nitrogenous fertilizers" by G. W. Winsor, *Rep. Exp. Res. Sta., Cheshunt, 1950*, pp. 61-2), and a brief account was given of the known properties of urea-formaldehyde compounds in relation to their possible use as nitrogenous fertilizers. The main interest of such materials lies in the possibility of preparing synthetic fertilizers of standardized properties to supplement or even replace the natural organic fertilizers such as hoof and horn.

In the work described in this report some urea-formaldehyde compounds were isolated in a relatively pure state for laboratory tests on their rates of decomposition in soil, and also in less purified form for glasshouse trials with tomato plants grown in pots. In the laboratory tests, measurements of the rates of mineralization of nitrogen in soils treated with these urea-formaldehyde compounds and with hoof and horn as a standard, showed a considerable range which seemed to indicate that one of the compounds in the series, trimethylene tetraurea, might prove of special interest. Unfortunately, attempts to prepare this compound have so far been unsuccessful, but further efforts are being made.

The pot tests with the crude products showed that one of them, of the methylene-urea type, has promise as a slow-acting fertilizer and gave a yield higher than that obtained from the conventional use of hoof and horn in the potting mixture with subsequent top dressings. Laboratory tests on the mineralization of the crude products showed that the results of the pot tests were related to the rates at which the compounds decomposed in the soil.

Boron in the Nutrition of the Tomato Plant

A study of the role of boron in the nutrition of the tomato plant was started at the Experimental and Research Station at Cheshunt in 1954. There is no reason to believe that boron deficiency is at all common in commercial tomato crops in this country, but numerous instances of

it have been recorded in America and on the Continent. It seemed therefore worth while to study the boron requirements of the tomato plant in some detail, as even in the absence of visual symptoms of deficiency the amount of boron available to the plant might sometimes be insufficient to maintain optimum growth and fruiting. The work at Cheshunt was based on sand culture experiments, and in these experiments definite symptoms of boron deficiency were reproduced and the need for an adequate level of boron in the nutrition of tomato plants clearly demonstrated.

At the Institute further work has been undertaken with plants grown in soil. In particular, the distribution of boron in relation to leaf position on the plant, seasonal trends in boron content of the leaves, and the effects of added boron on plants grown in a glasshouse border have been studied. For the latter, a replicated experiment was laid down in one of the trial glasshouses in a block where tomato plants grown in the previous year had shown a rather low content of boron in the leaves, and boron was applied either as a spray or in the soil. The added boron seemed to have no effect on crop yield, although the levels of boron in the foliage of the experimental plants was relatively low, but there was some suggestion of an improvement in fruit quality at the higher rate of soil dressing. This latter result needs to be treated with some reserve until comfirmatory evidence is obtained.

The pC test for Determining Soluble Salts in Soils

The effect on plant growth of excessive accumulations of soluble salts in old glasshouse soils is a subject that is much discussed nowadays, and in this country the level of these accumulations is commonly measured by the *p*C test. Some thousands of *p*C determinations are done annually by advisory officers and others, and the results are used rather arbitrarily as a guide to cultural practice. A certain amount of research on the relation between the growth of crops and the *p*C level in the soil is also being carried out.

There is reason to believe, however, that in some circumstances the conventional *p*C test may have only a limited value, and particularly is this likely to be the case in old glasshouse soils where the presence of large accumulations of calcium sulphate may give misleading results. The reason for this is that calcium sulphate is only sparingly soluble in water; in the soil, therefore, it will not be in solution to any great extent, but during the preparation of the watery suspension required for the *p*C test will be dissolved either wholly or in part. Thus the test will show a high concentration of soluble salts, but in the soil they may not be at such a level as necessarily to restrict plant growth.

A critical re-examination of the *p*C test has therefore been undertaken by means of experiments with pot plants. The work is only of a preliminary nature but has yielded some extremely interesting results. The effect of varying the amount of water used in preparing the soil suspensions required for the conductivity test has been studied, and the results compared with *p*C values obtained by using a saturation paste extract or a displaced soil solution. The ideal would be to determine the concentration of soluble salts in the soil solution in contact with the plant roots, and the conductivity of the displaced soil solution probably gives the nearest approach to this. The results did in fact show that the displaced soil solution gave the best correlation between *p*C values and plant growth, but unfortunately the method is unsuitable for routine use.

In an attempt to avoid complications arising from the presence of differing concentrations of calcium sulphate in the soil samples, further *p*C determinations were made in which an excess of pure calcium sulphate was deliberately added to all soil samples during preparation of the suspensions. This rather neat trick, although representing a more empirical approach to the problem, proved gratifyingly successful; the *p*C values obtained by this method, using conventional soil and

water suspensions, were found to have a very high and significant correlation with plant growth. This simple modification of the *p*C test shows promise, therefore, but it will need to be applied to a range of glasshouse soils before its value can be definitely asserted.

The Function of the Casing Layer in Mushroom Cultivation

The need for a casing layer to stimulate the fruiting of the cultivated mushroom has always presented a great mystery, and if the secret of the function of the casing layer could be revealed it might pave the way to vastly improved yields. The problem received much study at the former Mushroom Research Station at Yaxley, with particular emphasis on the physical aspects of the casing layer. Facilities were not immediately available to extend this work at the Institute, so it was decided to investigate two other aspects of the casing layer which have hitherto received little attention.

It is a generally held belief that the reason why the casing layer stimulates the mushroom to fruit is because it contains very little in the way of nutrients in contrast to the compost out of which the mycelium grows. This belief is based on the knowledge that with other fungi the production of fruit bodies is often induced by the impoverishment of the medium in which they are growing, or by deliberately encouraging them to grow from a rich medium to a poor one. With the mushroom there is very little direct evidence on this point, so it seemed important to examine the function of the casing layer from the nutritional aspect. Both organic and inorganic nutrients were added to the casing soil in pot experiments and the effect on fruiting studied.

When relatively simple chemical substances or dried compost were added to the casing it was found that there was no detrimental effect on the yield of mushrooms. These results offer no support, therefore, for the hypothesis that the initiation of fruiting is related to the difference in nutritional status between compost and casing layer. In two experiments with dried compost, one of which was carried out on shelf beds, there was, in fact, a considerable increase in yield, with a tendency for heavier mushroms to be produced, but the reasons for this have yet to be determined. In nearly all cases the addition of organic nutrients to the casing layer delayed the initial formation of pinheads, and cropping started a few days later than with untreated casing.

The second aspect of the casing layer that has been under study is the effect of adding salts to it. This is a practice adopted by some growers and it is believed to improve the quality of the mushrooms and to control certain diseases. Although experiments involving the addition of a variety of substances to the casing layer have been carried out in the past, the results were inconclusive and the matter has never been systematically examined.

It was found that the addition of inorganic salts to the casing soil had highly significant effects on fruiting, but the effects appeared to be very largely proportional to the amounts of salt added. There appeared to be little or no specific nutritional effect when salts containing nitrogen, phosphorus or potassium were added, the effects appearing to be mainly due to the amount of soluble salts in the soil. In these experiments it was found that the addition of salts to the casing layer led to the production of heavier mushrooms and thereby improved quality; the growers' practice referred to above thus received some support.

In an experiment in which sodium sulphate was added both to the compost and the casing soil evidence was obtained that there is considerable movement of salts from compost to casing, but further work must be carried out to determine whether this is likely to be of practical significance or not.

PLANT BREEDING

The Plant Breeder, Mr. L. A. Darby, took up his post at the Institute towards the end of 1955, having previously served in the Department of Genetics at the John Innes Horticultural Institution for some years. He has brought with him much useful experience in tomato breeding based on the valuable work done at that research station.

Initially the plant breeding programme is to be limited to improving the tomato and cucumber crops, with some attention being paid to lettuce. In 1956 variety trials with tomato and cucumber were carried out with material raised before Mr. Darby's arrival. The trials were laid out on modern statistical lines, but despite precautions taken to achieve uniformity at every stage they were much affected by environmental variations in the houses. This has limited the value of the results, which are briefly reported later in this issue, but the conduct of the trials has provided useful information and experience for the future.

PLANT PATHOLOGY

The Plant Pathology Department, under Mr. P. H. Williams, is at present concerned with three main disease problems of glasshouse crops, *Didymella* Stem Rot of the tomato, powdery mildew of the cucumber, and the wilt diseases of the carnation. Mushroom diseases are also studied.

Didymella Stem Rot of the Tomato

Didymella Stem Rot can be a devastating disease of tomatoes, both under glass and out of doors. While some aspects of control are understood, particularly those relating to hygiene, there are still a number of unresolved questions. Arising out of a suggestion made by the Institute's Research Committee a conference of workers concerned with the problem was convened by the Agricultural Research Council, in November 1956, to review the position and consider what further research was needed. The discussion ranged over a wide field, particular attention being paid to sources of infection and the prospects of controlling the disease by breeding for resistance or by safe chemical means. An account of the discussion was published in the commercial press (see, for example, The Grower, **47**, 7, 1957, 425-27).

An aspect of the disease that has been specially studied at the Institute is the behaviour of the causative fungus, *Didymella lycopersici*, in the soil. This has arisen out of earlier work at Cheshunt in which it was shown that the fungus will grow quite freely on sterilized soil, and will cause disease in tomato plants grown in such soil, but will often not become established on unsterilized soil, the majority of plants growing in it remaining healthy. It seems that in unsterilized soil the growth of the fungus is inhibited by some factor or other, and laboratory experiments have been carried out over a period, both at Cheshunt and at Littlehampton, to investigate this phenomenon. The work to date is summarized in this report.

The investigations included direct observation of the fungus spores in sterilized and unsterilized soil, a study of the possible toxic effect of the soil solution extracted from unsterilized soil on the fungus spores, and experiments designed to reveal the relation of other soil micro-organisms to the survival of the fungus spores. Direct observation under the microscope showed that in unsterilized soil spores of *D.lycopersici* either disappeared or, if they did germinate, the germ tubes remained short and soon ceased to grow. In sterilized soil, however, spore germination was normal and the fungus grew and eventually sporulated. There appeared to be no toxic factor in the soil solution from unsterilized soil which could account for the inhibition of the fungus in such soil.

In an experiment in which soil was steamed for various periods in order to change the balance of micro-organisms in it, the results suggested that bacteria and actinomycetes, rather than fungi, are more likely to be the source of the factor inhibiting the growth of *D.lycopersici* on unsterilized soil.

Cucumber Mildew

The study of powdery mildew on the cucumber is made difficult by the fact that the fungus is an obligate parasite and therefore can only be maintained on living plants. The laboratory technique, briefly mentioned last year, for maintaining pure cultures of mildews and preventing contamination during experimental transfers, has been developed and has proved extremely valuable in pursuing the work on cucumber mildew. The technique is described in detail in this report.

Using the method a considerable number of inoculations have been carried out to determine the true botanical identity of cucumber mildew, to investigate resistance to cucumber mildew within the family Cucurbitaceae, and to reveal plants which might be alternate hosts for the fungus causing cucumber mildew. Some work was also done on mildew of chrysanthemums and carnations. The inoculations within the family Cucurbitaceae showed that only species of *Luffa* are completely resistant to mildew, although *Ecballium elaterium* was only slightly infected in the laboratory and not at all in the greenhouse. The study of other hosts for cucumber mildew has particularly in view the problem of how cucumber mildew survives the winter in the absence of cucumbers. It seems possible that the fungus overwinters on one or more alternate host plants, possibly weeds around the nursery. Cross-inoculations showed that there are many plants which are susceptible to cucumber mildew, while mildew from a few naturally infected plants, among them the sowthistle, groundsel and the creeping buttercup, could be transferred to cucumber. This work was accompanied by spore trapping experiments which, however, gave very disappointing results. Experiments and observations have so far given no definite indication of the correct botanical identity of the cucumber mildew fungus.

Carnation Wilt Diseases

Continuing the investigation of carnation wilt diseases, methods of isolating the disease organisms have been tested and inoculation experiments have been carried out to study the progress of disease in infected plants. The work on isolation methods is particularly important in connection with the "culturing" technique now beginning to be used by growers for raising disease-free planting material. Special attention has been paid to methods of isolating the bacterium causing the new Slow Wilt disease. The inoculation experiments have shown that infection of plants through the roots or from the soil is a slow and variable process, but that infection through the ends of cuttings is more rapid, although it still produces variable symptoms.

Mushroom Diseases

Work on mushroom diseases has been confined to "La France" and similar disorders, and the investigations have been carried out in the growing house as well as in the laboratory. Cultures of mushroom mycelium isolated from samples of compost obtained from farms where the disease had occurred were found to show abnormally slow growth in petri dishes in the laboratory; the cultures were also different in colour and appearance from normal cultures, isolated from healthy commercial spawn, and showed very poor development generally.

In pot experiments in the growing house, the yield was generally much lower from spawn prepared from "diseased" cultures than from normal commercial spawn, and the cropping period was usually shorter. There was little abnormality in the shape of the mushrooms produced by the diseased spawns, however.

An interesting exception to these results was shown by a culture from a house on one farm in which the crop grew and yielded normally although the previous crop had been diseased. No special hygienic measures had been taken between crops. This culture grew normally in the laboratory and gave quite good yields in the pot experiment.

With "La France" and similar disorders a common feature is the abnormal growth of the sporophore, and a variety of shapes have been reported and described. To appreciate these abnormalities properly it has been necessary to define the normal mushroom. From a large number of measurements on many hundreds of apparently normal mushrooms it has been possible to set numerical limits to normality, and the work was presented in a paper for the Third International Conference on Mushroom Science held in Paris in 1956. The paper includes reference to measurements made on abnormal mushrooms produced under various growing conditions, and these studies have made it possible to draw up a provisional classification of the abnormalities so far encountered.

ENTOMOLOGY

The appointment of Dr. N. W. Hussey as Head of the Entomology Department led to some reshaping of the Department's programme and, in particular, preliminary attention was given to mushroom pests. Towards the end of the year arrangements were in hand for the appointment of an additional entomologist so that the work on mushroom pests could be extended. In this way it was hoped to fill an important gap in the organization inherited from the Mushroom Research Station at Yaxley. Work was continued on the Glasshouse Red Spider Mite, and studies were also begun on the effect of temperature on the development of the species of the Glasshouse White Fly. The investigation of White Fly has been in abeyance since measures for the control of the pest by means of the parasite *Encarsia formosa* were worked out at Cheshunt. Although the parasite is no longer being bred for distribution to growers, there is a need for basic information on the effects of the environment on the balance between white flies and their parasites against the time when control of the pest by biological means may again become possible.

Mushroom Pests

The investigation of mushroom pests was begun by studying the insects occurring in light stable manure when stacked for a period in the open, and in artificial compost during its preparation. In the first six months of observation a considerable range of insect species was found in the manure but, by contrast, the insect population of the artificial compost was relatively low. Large numbers of the Sciarid, *Sciara fenestralis*, were bred out from the compost just before it was placed in the growing beds, a fact of some importance bearing in mind the known habits of this insect as a mushroom pest. This and other Sciarids were also found in considerable numbers in the stable manure. It seems likely, therefore, that most Sciarids enter the houses with the compost. In a comparison of the insect faunas of spawned and unspawned compost it is of interest that the Phorid *Megaselia halterata* was found only in the spawned material. Phorids, therefore, may only infest mushroom houses after spawning.

These preliminary investigations were accompanied by the examination, at weekly intervals, of insects caught in a light trap installed in a growing house during cropping. Large catches of Sciarids were made, ranging over several species, and a most unusual feature of the results was the large number of *Scatopsids* trapped. There were also very large catches of Phorids, almost exclusively of the species *Megaselia halterata*, the Worthing Phorid Fly. Among the Cecids, relatively large numbers of *Heteropeza* adults were trapped eight weeks after the first flush and it would seem that this form is likely to be of most economic importance at the Institute.

Red Spider Mite

Continuing the studies on Red Spider Mite, experiments were carried out to determine the effect of temperature on the rate of development of the insect. Knowledge of the rate of development is of importance in deciding the intervals between applications of acaricides for controlling the pest. Investigating, first, the range between 70°F. and 95°F. it was found that the eggs hatched more rapidly as temperature was increased, both in long days and in total darkness. The study was continued to investigate the effect of temperature on the young stages of the insect. Again it was found that a definite relation exists between temperature and rate of development, the insects growing more rapidly as the temperature was raised, but in this case a peak seemed to be reached at about 85°F. The work is being extended into the lower temperature ranges and special attention is to be given to the effects of the wide daily range of temperature experienced in glasshouses.

CROP PROTECTION

The department formerly known as that of Insecticides and Fungicides has been restyled as the Crop Protection Department and, under Mr. W. H. Read, has continued its work on acaricides and fungicides, special attention being given to residues left on the plant after the use of the former. In the general field of acaricide synthesis and testing the main object is to find one which will control Red Spider Mite on the cucumber without causing harm to the plant. Some of the compounds tested have shown promise but are either too phytotoxic or involve some risk in use which must be investigated further before recommendations for use under glass can be made.

In the field of fungicides a large number of compounds were tested for the control of *Didymella* Stem Rot of tomatoes, a task made urgent by the withdrawal of ethyl mercury phosphate, formerly used for the control of this disease, because of hazards involved in its use. Unfortunately no compound of definite promise was found. Tests of compounds, mainly ones synthesized in the laboratory, for the control of Tomato Leaf Mould and Cucumber Mildew were also continued. One of these compounds appeared to be very effective and further work on it, together with the preparation and testing of other compounds in the same chemical series, will be carried out.

II. PLANT PHYSIOLOGY

1. GENERAL

In the continued absence of an experimental glasshouse and with the congested laboratories, expedients have again been necessary. These are, inevitably, time- energy- and money-wasting and produce experimental results of restricted value.

A temporary field laboratory has been erected at the north end inside one of the "trial" glasshouses (C2) to accommodate electric recording equipment used in environmental measurements. With this expedient, preliminary tests have been made with the temperature, humidity and radiation recording apparatus.

In this and the neighbouring glasshouse (C1) soil moisture tension variation was studied using mercury-in-glass or in-nylon manometers. Tomato plants were grown closely or widely spaced and the soil moisture tension observed at two distances from the plants, together with growth and yield observations. Preliminary tests with potted plants were made, preparatory to using a large capacity balance in transpiration experiments in conjunction with the recording, null method tensiometer.

In another glasshouse (D3) growth observations on the tops of tomato plants were made repeating the comparison of retaining or removing laterals that was made last year. On nine occasions the desired night minimum temperature could not be maintained.

In the remainder of this glasshouse crop records were made on plants (i) with all laterals removed, (ii) with all laterals below the first truss present, the remainder removed, (iii) as (ii) but with subsequent laterals below each of the successive trusses on the main stem allowed to develop until six main stem trusses had been produced, subsequent laterals being removed, and (iv) as (iii) but all truss laterals allowed to develop. The results are undergoing analysis.

2. SOME 1956 GROWTH ANALYSIS OBSERVATIONS ON THE TOMATO

by

A. J. COOPER

For three years plants of the Potentate variety of the tomato were grown with the shoots allowed indefinite extension in the environment and physical size limits of a commercial type glasshouse, and the development of the shoots, leaves and fruit was measured at weekly intervals, both on plants from which all axillary shoots were removed and also on plants on which all first order axillary shoots developing on the main stem were retained and second order axillary shoots removed. The observations made in 1956 concluded the first stage of the growth analysis work on the tomato.

The plants were grown six feet apart to reduce competition between them, and the lengths of the shoots, the lengths of the leaves from the axils to the tips and the diameters of the fruit were measured weekly. The diameter measurements were converted to the cubes of the radii to provide an estimate of fruit volume.

An attempt was made to ensure that soil moisture and soil nutrients were at no time limiting growth but, with the present state of knowledge on the subject, it was not possible to be certain that the attempt was successful.

Results

The mass of data that is collected in a detailed growth analysis takes considerable time and labour to analyse and consequently the analysis is in the early stages. One fact that is apparent is that in 1956 there was a regularly recurring pattern of axillary shoot growth with progress up the main stem. In Figure 1 are shown the final lengths attained by the main stem and all the axillary shoots of one of the plants when the experiment was concluded in October. The lengths of the axillary shoots are shown by horizontal lines, and the positions of the flower trusses on the main stem by solid circles.

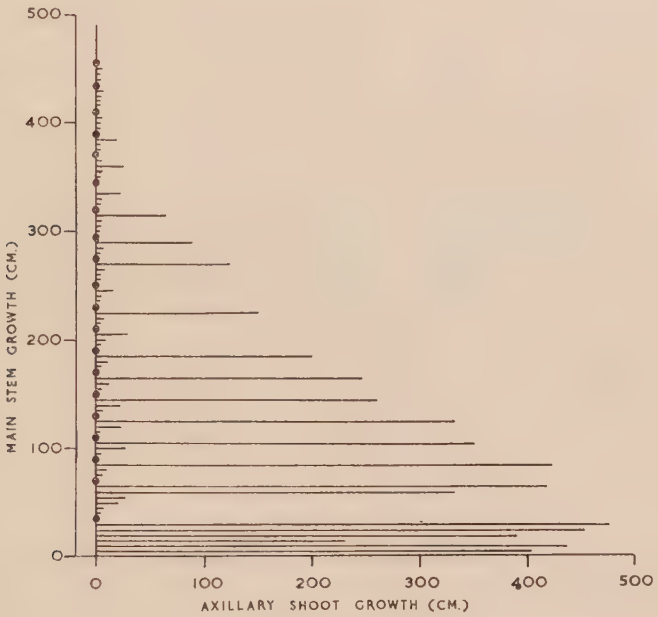

FIGURE 1. Pattern of vigour of axillary shoot growth.

The pattern of axillary shoot growth was related to the position of the flower trusses on the main stem, the most vigorous shoots being those that arose in the axils of the leaves immediately below trusses. The growth of shoots arising in the axils of the leaves immediately above trusses was practically inhibited, while intermediate axillary shoots exhibited intermediate degrees of vigour. The vigour of growth of all the axillary shoots arising below the first truss (i.e., not only the shoot immediately below the first truss but those arising lower down the main stem as well) was similar to that of an axillary shoot arising immediately below a truss.

In Figure 2 are shown the weights of ripe fruit picked from the main stem and the axillary shoots of the same plant. It can be seen that the pattern of fruit production in terms of weight is similar to the pattern of axillary shoot extension growth since, almost without exception, the shoots that bore fruit were all those below the first truss and those arising immediately below the successive trusses on the main stem.

The correlation coefficient for axillary shoot length and the weight of fruit borne by the axillary shoots was 0.92 and was significant at the 0.01 level of probability.

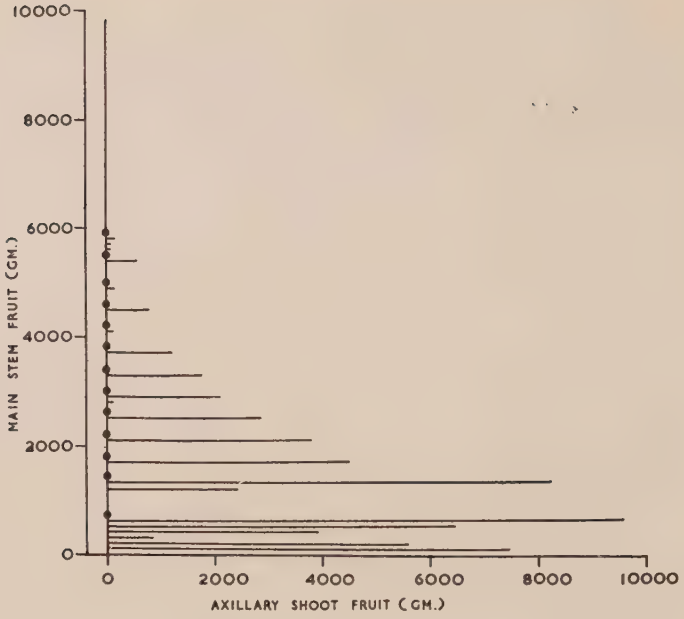

FIGURE 2. Pattern of fruit production on axillary shoots.

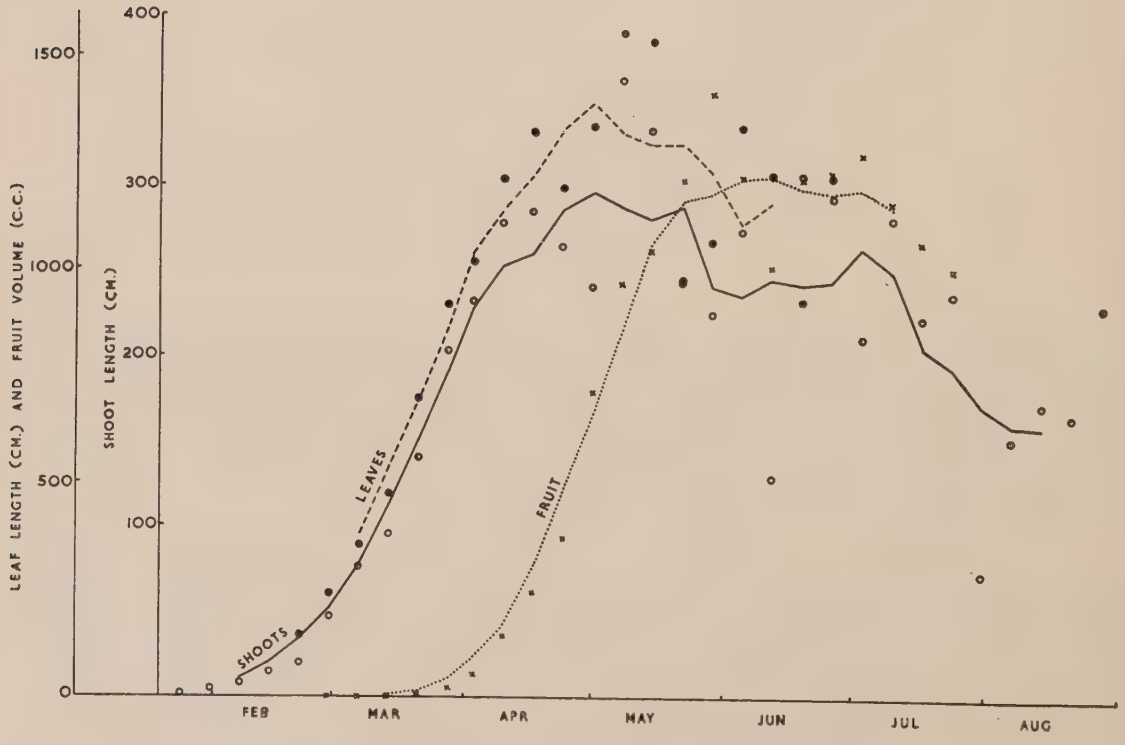

FIGURE 3. Weekly rates of growth of shoots, leaves and fruit.

The mean weekly absolute rate of shoot extension growth of the main stems and axillary shoots of the two plants on which all first order axillary shoots were retained is shown in Figure 3. The weekly growth rates are indicated by open circles and the continuous line shows the moving average based on five weeks' data, i.e., any position on the line is influenced by both the preceding and succeeding two weeks' data. It can be seen that in 1956 the weekly rate of shoot extension growth increased steadily until early May when a check occurred.

To present data on leaf development comparable with those on shoot growth the mean weekly rate of total leaf length production for the two plants was calculated. The rate in any one week was obtained from the equation:—

$$P=(a_2+b_2)-(a_1+b_1)$$

where P=the weekly rate of leaf length production

a=leaf length present on plant

b=accumulated total of leaf length removed

$_1$=first week under consideration

$_2$=second week under consideration.

The broken line in Figure 3 shows the moving average based on five weeks' data and the weekly rates are shown by solid circles. It can be seen that a check to leaf growth occurred in early May in 1956 at approximately the same time as the check to shoot extension growth occurred.

The method used to calculate the leaf growth data was also used to obtain comparable data on fruit development, **P** representing the weekly rate of fruit swelling in c.c., **a** the fruit volume on the plant and **b** the accumulated total of fruit volume picked. In Figure 3 the dotted line indicates the moving average based on five weeks' data and the weekly rates are shown by crosses. It can be seen that a check to the steadily increasing rate of fruit swelling occurred in late May 1956, approximately three weeks after the check to the development of the leaves and the shoots occurred.

The above observations are merely intended as factual observations on the development of plants of the Potentate variety of tomato under the experimental conditions prevailing in 1956. It is not possible to interpret the data of one year in isolation.

3. 1956 OBSERVATIONS ON THE EFFECT OF THE RETENTION OF SELECTED AXILLARY SHOOTS ON THE CROPPING OF THE POTENTATE VARIETY OF TOMATO

by

A. J. COOPER

It has been shown (Cooper, 1955) that there is a regularly recurring pattern of axillary shoot growth with progress up the main stem of the Potentate variety of tomato, and that the more vigorous axillary shoots bear fruit of a total weight comparable with that borne by the main stem.

It has also been shown (Cooper, 1955a) that in late April/early May in the south of England a check in the growth of the main stem and axillary shoots of the same variety of tomato occurs. Subsequent growth analysis, the results of which are awaiting publication, has shown that this check occurs at the same time each year despite differences in the stage of development of the plant and the seasonal conditions.

The first half of a trial was laid down in 1956 in a vinery type glasshouse (D3) to test a possible commercial application of these two facts.

Technique

Three pruning treatments involving the retention of selected laterals were compared with single stemmed plants from which all the axillary shoots were removed. The treatments were as follows:

Treatment 1. All the axillary shoots were removed.

Treatment 2. All the axillary shoots below the first inflorescence on the main stem were retained and all others were removed.

Treatment 3. All the axillary shoots below the first inflorescence were retained as well as the axillary shoot arising *immediately* below each inflorescence up to and including the sixth inflorescence on the main stem. All the axillary shoots above the sixth inflorescence were removed as well as the axillary shoots (other than those retained as described) that arose between the first and the sixth inflorescences.

Treatment 4. All the axillary shoots below the first inflorescence were retained as well as the axillary shoots arising immediately below each inflorescence on the main stem. All other axillary shoots were removed.

The growth of the main stem was stopped in all treatments by the growing point being removed two leaves above the fourteenth inflorescence. The growth of the axillary shoots was stopped when they approximately reached the level of the overhead wires, i.e., two leaves above the following inflorescences:

Axillary shoot	1	Inflorescence	13
,,	,, 2—7	,,	12
,,	,, 8	,,	11
,,	,, 9	,,	10
,,	,, 10	,,	8
,,	,, 11	,,	7
,,	,, 12	,,	6
,,	,, 13	,,	5
,,	,, 14	,,	4
,,	,, 15	,,	3
,,	,, 16	,,	2
,,	,, 17—20	,,	1

Second order axillary shoots developing on first order axillary shoots were removed as soon as practicable.

The four treatments were compared using a randomised block layout of five plants in each treatment plot with four replications. The plants were sited 6 ft. apart to reduce competition between the plants, using a square planting layout.

The seed was sown on November 22nd, 1955, and on January 14th, 1956, when the fifth leaf was just visible, planting was carried out. Throughout the trial the plants were watered at regular weekly intervals and the 6 ft. square area of soil in which each plant was growing was given the same metered quantity of water irrespective of the pruning treatment applied. The amount

of water applied was increased as the plants grew and by means of auger borings a constant check was maintained to ensure that the soil remained very moist down to a depth of three feet in an attempt to ensure that soil moisture was not a limiting factor in any treatment. In a similar attempt to ensure that soil nutrients were not limiting, nitro-chalk and a proprietary potash-phosphate fertiliser were applied with alternate waterings at the rate of one ounce per square yard each over the whole glasshouse area *irrespective* of pruning treatments. This manurial treatment was chosen arbitrarily since there appear to be inadequate data in the literature to provide a rational guide when endeavouring to ensure that soil nutrients do not constitute a limiting factor at any stage of growth of the Potentate variety of tomato.

The night minimum temperature as measured 4 ft. from the ground in a Stevenson screen was maintained as near to 57°F. as the heating system allowed. No shading was applied to the glass-house roof and the day maximum temperature was maintained by ventilation below 70°F. for as long as weather conditions permitted.

Results

Fruit at the normal stage of maturity for marketing was picked daily, commencing on May 5th. The mean total weight of ripe fruit per plant that was picked in each treatment, the mean fruit size and the percentage of the fruit that were uniformly coloured, are shown in Table I. The grading for uniformity of colouring was extremely strict and fruit that had the slightest trace of uneven colouring were rejected from the uniformly coloured grade.

TABLE I

Effect of Pruning Treatments, involving the retention or removal of selected lateral shoots, on mean weight and size of tomato fruit and on the proportion of uniformly coloured fruit

Treatment	Mean weight of ripe fruit per plant	Mean fruit size	Mean uniformly coloured fruit
	g.	*g.*	%
1	16,458	81	44.6
2	49,278	66	63.5
3	50,120	65	69.7
4	50,405	63	70.7

The total yield from the single-stemmed plants was significantly smaller (P=0.01) than the yield from the multi-stemmed plants. There were no significant differences, even at the 0.05 level of probability, between the weights of fruit borne by the three multi-stemmed pruning treatments tested.

The mean fruit size of the single stemmed plants was significantly larger (P=0.01) than that of the multi-stemmed plants, but again there were no significant differences (P=0.05) between the mean sizes of the fruit from the multi-stemmed treatments.

There was a much lower percentage of uniformly coloured fruit on the single-stemmed plants than on the multi-stemmed plants (P=0.01). The multi-stemmed plants with the smallest number of laterals (Treatment 2) bore less uniformly coloured fruit (P=0.05) than did the plants in Treatments 3 and 4, but there was no significant difference between these last two treatments at the 0.05 level of probability.

Thus, if a reduction in mean fruit size and an increase in the percentage of uniformly coloured fruit borne is regarded as an improvement in quality in the Potentate variety of tomato, it is possible to conclude that *under the conditions of the experiment in the one year considered* the retention of selected axillary shoots improved the quality of the fruit and increased the total yield *per plant* (not necessarily per unit area of glasshouse soil).

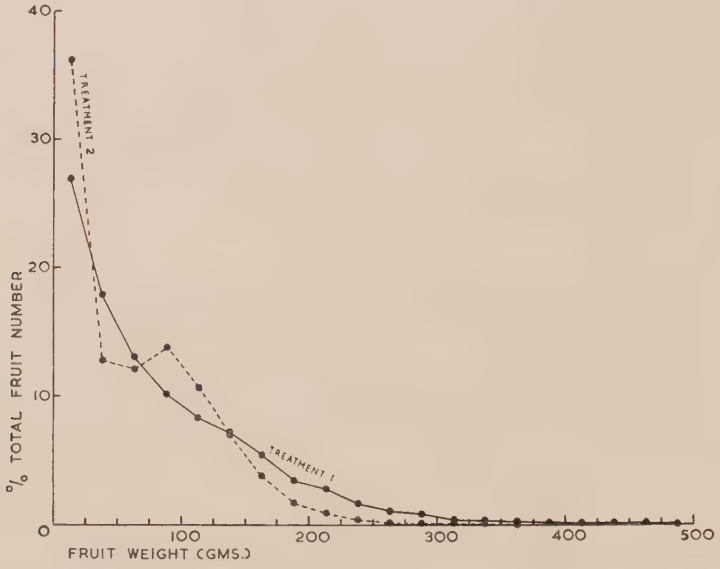

FIGURE 1. Proportion of fruit picked in each weight grouping from plants without axillary shoots (Treatment 1) and with axillary shoots (Treatment 2).

In Figure 1 are shown the data obtained from individual weighings of 19,167 fruit from Treatments 1 and 2. The number of fruit occurring in size groupings of 25 grams (e.g., 26—50 grams, 51—75 grams, etc.) have been plotted as a percentage of the total fruit number picked in each treatment. The data for the single-stemmed plants (Treatment 1) are indicated by the continuous line, while the data for the multi-stemmed plants (Treatment 2) are indicated by the broken line. It can be seen that the multi-stemmed treatment reduced the percentage of very small fruit of 25—75 grams and the percentage of very large fruit of more than 150 grams, while the percentage of medium sized fruit of 75—150 grams was increased. These data further support the contention that in 1956 under the conditions of the experiment the retention of selected axillary shoots improved the quality of the fruit in regard to size in the variety Potentate.

Although there was an increase in the total yield per plant from the retention of selected axillary shoots there was a decrease in the early yield. In attempting to evaluate the economic importance of this reduction in early yield relative to an increased total yield it became apparent that neither total yield nor early yield over a specified number of weeks had much meaning as criteria of the effect of a given treatment, since the market price of a pound of tomatoes is a dynamic quantity.

To develop a criterion that was independent of this criticism, use was made of the London market prices throughout the season for 12 lb. of pink and white grade tomatoes as given in the Journal of the Tomato and Cucumber Marketing Board. A "market factor" was obtained by dividing the price on any day by the lowest price in the season. These market factors have been plotted for 1955 and 1956 in Figure 2. It can be seen from the Figure that in 1955, for example,

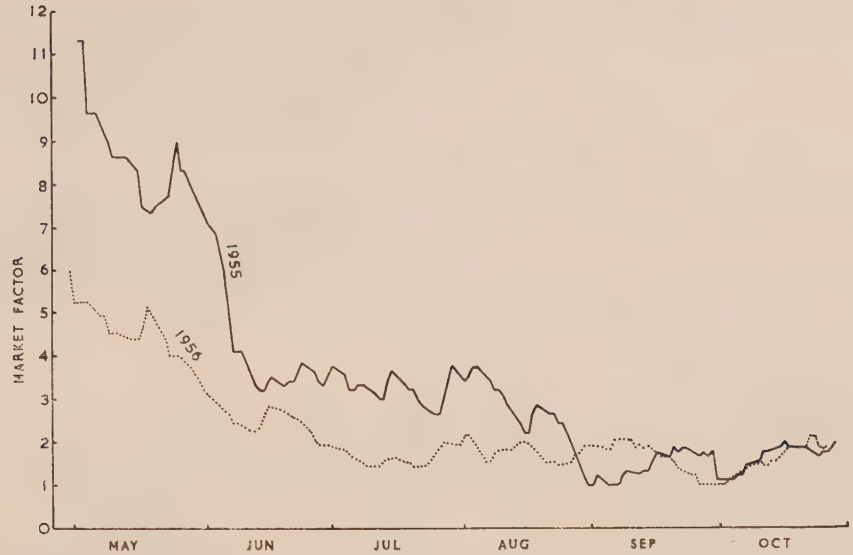

FIGURE 2. Market factors (1955 and 1956) for estimating equivalent market yield from actual yield.

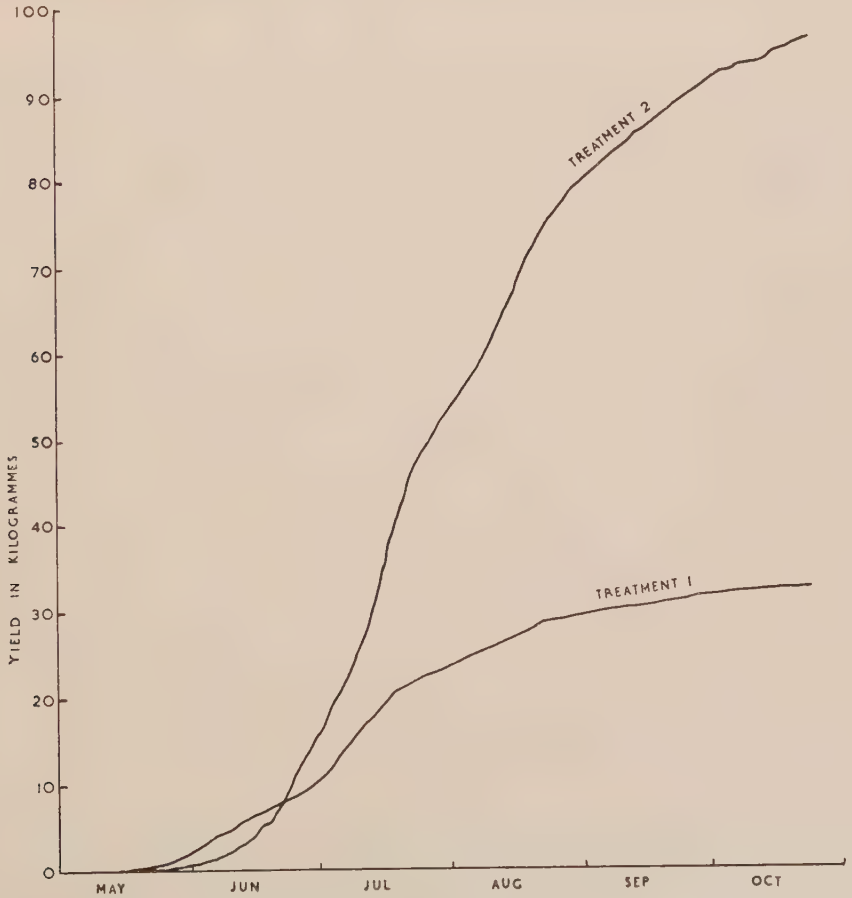

FIGURE 3. Accumulated actual yields from plants without axillary shoots (Treatment 1) and with axillary shoots (Treatment 2).

1 lb. of tomatoes picked on the 5th May was equivalent to 10 lbs. of tomatoes picked on the 1st September. Thus, if the actual yield on any day is multiplied by the market factor for that day, an equivalent market yield is obtained that enables a direct comparison between two treatments to be made, since the criterion of equivalent market yield makes due allowance for market price and the relative importance of early yield and total yield is evaluated.

In Figure 3 the accumulated actual yields for Treatments 1 and 2 are shown and it is possible to draw the conclusion that in 1956 Treatment 2 increased the total yield per plant 2.95-fold, but that there was a decrease in early yield for the first 4-5 weeks of picking. It is not however possible to draw any conclusion concerning the economic importance of this decrease in early yield because of the unassessed factor of market price.

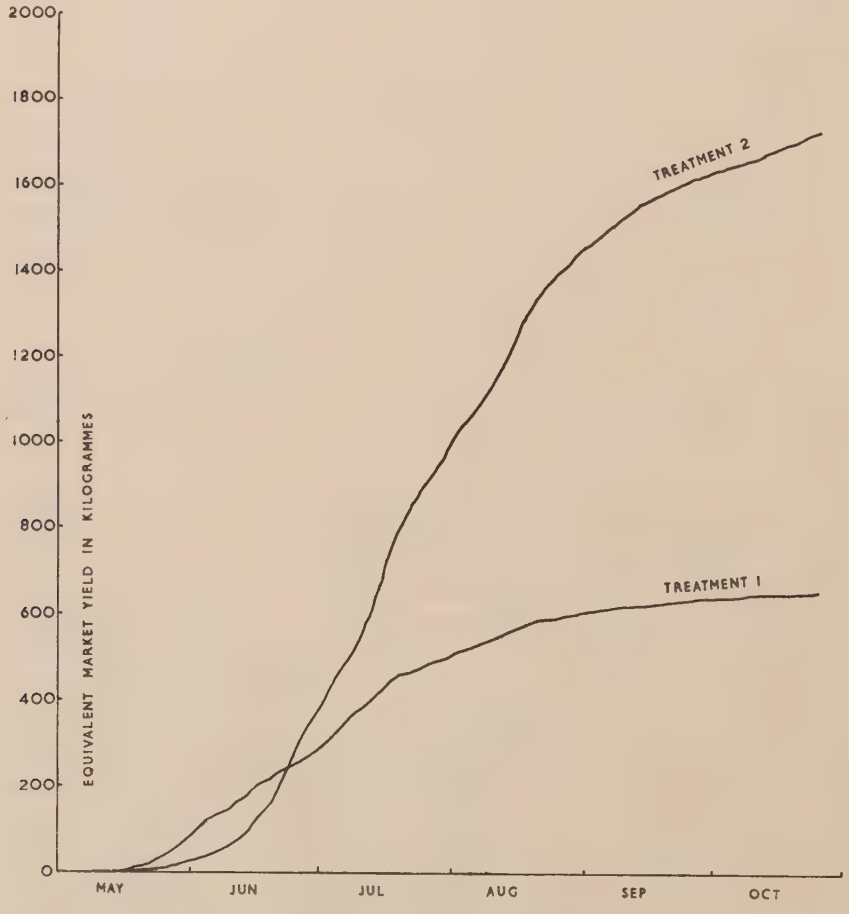

FIGURE 4. Accumulated equivalent market yields from plants without axillary shoots (Treatment 1) and with axillary shoots (Treatment 2).

In Figure 4 the accumulated equivalent market yields for the same treatments are shown, and using this criterion instead of actual yield it is possible to conclude that, when the effect of the reduction in early yield is taken into account, Treatment 2 in 1956 increased the true economic yield per plant (excluding differences in production costs) only 2.65-fold and not 2.95-fold.

The development of a criterion such as equivalent market yield is essential if a correct economic interpretation of much applied work is to be made. The development of such a criterion needs the attention of an economist if much reliance is to be placed on it. It is beyond the scope of Plant Physiology.

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4. BLOTCHY RIPENING AND ALLIED DISORDERS OF THE TOMATO: A CRITICAL REVIEW OF THE LITERATURE

by

A. J. COOPER

It is not easy to define the physiological disorder of tomato fruits known as blotchy ripening because different people have used the term "blotchy ripening" in different senses.

The first mention of "blotchy ripening" in scientific literature seems to have occurred in 1921 in the Annual Report of the Cheshunt Experimental Station, and in the original definition fruit that were described as "Grade E—Blotchy fruit which ripen irregularly" were fruit that had hard green areas, around the calyx or elsewhere, in which the vascular bundles might or might not be discoloured, when the remainder of the fruit was red.

In 1925 the first detailed paper by Bewley and White on the work on blotchy ripening carried out at Cheshunt appeared in the Annual Report. In this paper a more specific definition of blotchy ripening was made. Fruit described as "possessing a hard green area around the stalk end" were apparently removed from the Grade E category of blotchy fruit and "true blotchy ripening," as it was named, was defined as a disorder in which the fruit had hard green areas "in any position" on the fruit ("not confined to the stalk end"), the vascular bundles in these areas being sometimes brown and necrotic, or clear glassy areas in which the vascular bundles were always brown and necrotic, when the remainder of the fruit was red.

In 1933 the Cheshunt workers (Bewley, Read and Orchard) again listed the types of non-uniformly coloured fruit previously described and also defined another type distinct from "true blotchy ripening", namely a yellow mottle on a red background, which they stated was "due to imperfect plants and high temperatures."

This, then, is the position today as far as British scientific literature is concerned, for no research worker in the United Kingdom since 1933 seems to have modified this definition.

In 1936, two Americans, Seaton and Gray, re-defined blotchy ripening as a disorder in which areas of the fruit remained hard and green. They did not incorporate the Cheshunt workers' separation of green areas around the calyx and "true blotchy ripening" since the position of the green areas was not made an essential part of their definition. Their definition also did not allow the Cheshunt contention that clear waxy areas were more severe cases of blotchy ripening but described them merely as a later stage in the ripening of hard green areas. They also showed that

only parenchyma adjacent to the vascular bundles was brown and necrotic and not, as defined by the Cheshunt workers, the bundles themselves. They stated that, "In severe cases of blotchy ripening, large, dense masses of dead cellular material are found to occur in the bundles in such manner that even the tracheae *appear* affected . . . . The cells that are actually affected include, for the greater part, the thin-walled parenchyma of the vascular rays, while the tracheae are uninjured . . . . Histological examination reveals that the discoloured tissues are *in all cases* parenchyma of the fleshy layer and that the bundles are not involved . . . . Cavities in the bundles result from a collapse of the vascular ray parenchyma which is pulled in around the unaffected tracheae."

In 1953 two New Zealand workers, Kidson and Stanton, published a paper in which they defined a disorder very similar to the Cheshunt definition of blotchy ripening, giving it the name of "cloud". Kidson and Stanton's definition differed from the Cheshunt definition and from Seaton and Gray's definition, however, over the location of the necrotic tissue. Kidson and Stanton stated that the necrosis affected both the "vascular system and surrounding parenchyma cells."

In 1954 an Italian, Gigante, published a paper containing yet another definition of blotchy ripening as a disorder in which "green or yellowish areas were irregularly distributed over the red surface of ripe fruits." On cutting open affected fruit it was stated that "brown striations are clearly visible corresponding to the courses of the vascular bundles and giving the impression of necrosis of the vascular elements". Gigante carried out a detailed histological examination of the necrotic tissue and stated that "the browning of the bundles is only apparent. The wood vessels and other xylem elements are in normal contact and the phloem too appears normal without any visible degeneration. The necrosis however, affects the parenchyma surrounding the vascular bundles, while the bundles themselves remain normal. Thus they take on a brown colouration through being enveloped in layers of necrotic cells."

Thus in the scientific literature there are several definitions of blotchy ripening, and, in any attempt to sort out the confusion that surrounds blotchy ripening, one of the first requirements is the accurate description of the symptoms of the disorder, or disorders, that are covered by the general term of uneven ripening. The applying of specific names, such as green-back, hard core, blotchy ripening, waxy-patch, cloud etc., to what may be different disorders with very similar symptoms, or which equally well may be merely different stages of development of the same disorder, only serves to confuse the picture by implying that the disorders so named are distinct one from the other without first proving that they are.

One point on which there is no conflict of opinion is that of varietal susceptibility. In a review of the work on blotchy ripening carried out at Cheshunt up to 1925 it was stated that "A certain amount of varietal susceptibility to the causes underlying blotchy ripening undoubtedly exists, but no variety remains consistently free from this disorder" and Seaton, in a paper published in 1936 in the Annual Report of the Vegetable Growers Association of America, supported this view by reporting that "A large number of varieties and strains have been tested in the hope of finding one that was not susceptible to blotchy ripening. Though slight differences have been observed, no variety has been found to date which is free from the disorder. In general those varieties which set heavily on the lower clusters produce fewer blotchy fruits than those in which only light settings occurred."

Thus it seems safe to conclude that there is general agreement that all varieties are susceptible to blotchy ripening but that some varieties are more susceptible than others.

The second and last fact about which there is a fair measure of agreement is the pronounced seasonal occurrence of blotchy ripening. There is no doubt that in some years the disorder is more severe than in others.

In 1925 the Cheshunt workers stated that "it is apparent . . . . that a certain proportion of the fruits become blotchy even when the soil is liberally manured . . . . other factors probably climatic in nature play some part in the incidence of this disorder." In 1938 White, one of the Cheshunt workers, wrote "Figure 1 gives the annual variations in proportion of blotchy fruit from plants grown during the period 1921-9 on plots from which nitrogen and potassium, respectively, were omitted continuously from the scheme of manuring. Figure 1 shows that the annual fluctuations of one plot correspond with those of the other. It follows that there must be a third factor, affecting both plots, involved in the production of blotchy fruit. This factor is probably light." In 1944 Clarke, working in Eire, wrote "It is worthy of note, however, that in the 1941 season when the total sunshine during the experiment was greater than in the 1942 season, there was less blotchy ripening in all treatments." Kidson and Stanton in New Zealand also reported that "It has been found that under similar cultural conditions the amount of cloud has varied considerably from season to season. Thus in the 1950-51 season plants were relatively free from the disorder while in the 1951-52 season the incidence of cloud was very high."

Thus there is general agreement that blotchy ripening has a pronounced seasonal association. Some attempt has been made to ascribe this to the effect of sunshine, but since the seasonal association is the only fact about which there is general agreement, other than the degree of varietal susceptibility, a more detailed investigation of the cause of the seasonal effect would be of considerable value.

There also seems to be little doubt that if tomato plants are grown under extremely low fertilizer treatment blotchy ripening will be severe since it is stated in the Cheshunt Annual Report for 1925 that "a block of four houses was erected on grassland which had been undisturbed for countless years. These houses were set apart for experiments which necessitated leaving one house unmanured, while the remaining three were given liberal dressings . . . . The crop yields for the first year clearly show that the percentage of blotchy fruit, averaging 4.15% in the well manured houses and 49.75% in the unmanured house, is dependent upon manurial treatment. Similar results were obtained in 1924 and 1925." It was also claimed in the same report that withholding either nitrogen or potash completely from the plants had a similar though less pronounced effect and it was stated that "the percentage of blotchy fruit is reduced by the application of nitrogen as sulphate of ammonia and potash as sulphate of potash."

The next person to work on the effect of manuring was Seaton, and in the Annual Report for 1936 of the Vegetable Growers Association of America, he stated that "Bewley and White at the Cheshunt Experiment Station in England from their results over a 5 year period (1921-25) concluded that 'blotchy ripening of tomato fruits is the result of malnutrition in respect of potash and nitrogen' and 'may be reduced to less than 1% by suitable applications of sulphate of potash and sulphate of ammonia.' Under our conditions in America where these and other fertilisers were applied in various amounts and in different combinations, no apparent reduction in blotchiness was secured. On one plot where 4,800 lbs. of muriate of potash per acre was applied during the year . . . . no significant reduction in the number of blotchy fruits was secured. Throughout our experiments, by the use of soil tests we have endeavoured to have a readily available supply of nutrients at all times. By the use of these tests in commercial ranges we have been unable to establish any relation between the presence or absence of mineral nutrients and the occurrence of the disorder. Several characteristics of the disorder are unexplainable on the basis of nutrient deficiencies."

The next paper to appear on the effect of manuring was that published by White in 1938 in which he considered some of the work carried out at Cheshunt after applying statistical tests to the data where it was possible. He came to the conclusion that "The outstanding feature . . . . is the high degree of significance of the interaction between treatment and season, and this effect

outweighs that of treatment," thus providing another indication that an investigation of the cause of this seasonal effect would provide information relevant to an understanding of the disorder.

The next person to work on manurial treatment was Clarke in Eire in 1944 who studied the effect of different amounts of potash on blotchy ripening in the variety Potentate. He concluded that "There was no clear-cut relationship between potassium and the physiological disorder known as blotchy ripening," and went on to say that "While it is true that some fruits of the no-potassium plants were blotched, the fruit in general from these plants coloured evenly . . . . a certain amount of blotchy ripening occurred at all levels of potassium during the course of these experiments." He continued by saying that "The observations here are not quite in agreement with the findings of Bewley who states that blotchy ripening is the result of malnutrition in respect of potassium and nitrogen, especially the former . . . . . the present work, which infers that sunlight is more important than potassium in reducing blotchy ripening is in accord with that of White who suggests that the trouble is not due directly to lack of potassium or nitrogen."

The most recent work on this subject has been carried out in Ohio by Jones. A brief note on this work which appeared in Phytopathology in 1956 suggested the possible existence of an interaction between the effects on blotchy ripening of potassium and temperature. Examination of the M.S. Thesis submitted by Jones at Ohio State University suggested that under commercial conditions of temperature there was no relationship between potassium and the incidence of blotchy ripening. In correspondence about this Jones stated that "In Ohio commercial tomato greenhouses the picking season consists of the months April through July . . . . If the period from April 18th through July 12th is regarded as the entire picking season, then the following statement can be made:— There was neither a significant inverse relationship between the percentage blotchy ripening occurring and the amount of potassium supplied to the plants when the temperature regime was abnormal nor a significant relationship when the temperature regime was normal."

Gigante, although he carried out no direct experimental work on the effect of nutrition on blotchy ripening, expressed an opinion based on his observations on the occurrence of the disorder in Italy, and stated "it does not seem likely that the blotching is related to a deficiency of nitrogen and potash as Bewley and White believe. I have found blotchy fruit growing in soils liberally supplied with nitrogen fertilisers and in those containing abundant potash."

Fairly recent work on the effect of mineral nutrition has been carried out in New Zealand by Kidson and Stanton. It is not quite so easy to summarise their opinion, though, since in one part of their published work they state that "Under certain conditions potash in excess of the amount supplied in the standard fertiliser has reduced the susceptibility of the plant to cloud . . . . In the early stages of the experiment the extra potash was without apparent effect on cloud. Some reduction in the amount of affected fruit appeared as time went on, but not enough to suggest that the disorder is directly associated with a shortage of potash." In another part they state that "Though extra nitrogen applications have proved beneficial there appears to be no definite correlation between total available nitrogen or between nitrate or ammonia content of the soil and the incidence of cloud." Elsewhere they state that cloud "has been decreased . . . . by very heavy dressings of potash during the winter and by the frequent application of nitrogenous fertilisers and muriate of potash throughout the season." Some of the data they present confirm the conclusions of White about the dominating effect of season, as in 1951 the application of extra nitrogen reduced blotchy ripening from 9 affected fruits per 10 plants to 1 fruit, whereas in 1952 blotchy ripening was reduced from 88 fruits per 10 plants to 38 fruits. Thus once again the effect of this unknown factor associated with season was far more important than the effect of manuring.

And yet this seasonal factor has never been determined. White, who did a little work on the subject, stated that "This factor is probably light," and then went on to say "It is of interest to note that a definite positive correlation between blotchy fruit and high temperature cannot be traced. The correlation coefficient between daily maximal temperature and the values for blotchy fruit is a statistically insignificant value." This suggestion that blotchy ripening is not associated with high temperature may not be justified, since White showed that there was no relation between daily maximal air temperature and blotchy ripening whereas the all-embracing term " high temperature" includes such things as, for example, high temperature of the fruit tissue due to sunlight falling on the fruit, and the use of the daily maximal air temperature alone completely omits the time-temperature relationship. Seaton, in the M.S. Thesis, which he submitted in 1933 to the Michigan State College of Agriculture, incorporated one aspect of the time factor by determining the weekly accumulated degree hours over a base of 70°F. and comparing this with the weekly percentage of blotchy fruit occurring. He stated that "the percentage of blotchy fruit follows rather closely the variations in the weekly excess temperatures. It is interesting to note that in most cases there is a lag of approximately one week between the influence of temperature and the amount of blotchy fruit." In the botanical literature there is a considerable body of evidence to support the suggestion that the rate and type of pigmentation of the tomato is very dependent on the temperature of the fruit tissue.

To turn to the basic facts of colour change during ripening, as far as they are known, it has been shown that as a tomato fruit ripens normally the green colouring matter disappears and as it does so, two other pigments appear, a yellow one known as carotene and a red one known as lycopene.

That temperature can affect normal ripening there is no doubt. Vogele, an American, ripened tomatoes picked at the mature green stage and found that "tomatoes when ripened at 104°F. do not turn yellow but remain green, i.e., chlorophyll decomposition is prevented." Thus it is feasible that the green patches on a red background characteristic of blotchy ripening could be caused by the sun shining through the leaves on to part of a tomato fruit and raising the temperature of the fruit surface at that point to about 104°F. and so preventing chlorophyll decomposition. The part of the fruit so affected would thus remain green.

Similarly Vogele found that fruits ripened at 97°F. and 90°F. were bright yellow i.e. chlorophyll decomposition was not prevented as at 104°F. but only the yellow pigment, carotene, was formed, the formation of the red pigment, lycopene being completely inhibited. Fruit ripened at 82°F. and 75°F., on the other hand, were an orange-red in colour, i.e., some of the red pigment was formed as well as the yellow pigment, the presence of the two together giving the fruit a deep orange-red colour. In the paper which he published on this work Vogele wrote that "The optimum temperature for lycopene formation in the tomato was found to be 75°F. Lycopene is not formed at temperatures above 86°F. When tomatoes are ripened at 90°F. to 100°F. bright yellow fruits are produced. When such yellow fruits are returned to 68°F. to 75°F. lycopene is developed normally. Chlorophyll decomposition in tomato fruits is prevented by a temperature of 104°F. or higher. Such fruits remain green and neither produce lycopene when returned to a temperature of 68°F. nor the yellow pigment when returned to 90°F."

Vogele's work was carried out with picked fruit ripening off the plant, but there is evidence in the literature that his findings would be applicable to fruit ripening on the plant. Three Americans working in New York State grew tomato plants in pots in a house kept at a temperature of 60°F. by night and 80°F. by day. When the first fruit showed signs of ripening they moved one third of the plants into a house kept 20°F. cooler, one third into a house 20°F. hotter, and left one third where they were. Paper shades were placed over the fruit to prevent the sun raising the temperature of the fruit above the air temperature of the houses. In discussing the results it was stated

that "the best coloured tomatoes were produced in the medium temperature range . . . . at this temperature all the tomatoes were definitely well coloured. They also had a strikingly higher lycopene content and a slightly higher carotene content than the tomatoes ripened at either 20°F. higher or 20°F. lower temperature . . . . At the low temperature range . . . . the tomatoes were fairly red in color but the red was not quite deep enough for them to rate U.S. No. 1 in colour. At this temperature they ripened very slowly and the fruits would get too soft and subject to decay before attaining a deep red color . . . . At the highest temperature range. . . . all the tomatoes turned yellow or orange in color as they ripened." Thus there is little doubt that Vogele's work with detached fruit is largely applicable to fruit ripening on the plant.

It is thus possible that blotchy ripening may be caused by the raising of part of a fruit above 86°F., the temperature above which lycopene formation is inhibited, while the remainder of the fruit is below 86°F. That a temperature gradient can be established across a tomato fruit by sunlight has been shown in California where it was found that the part of a tomato fruit on which the sun is shining may be 20°F. hotter than the shaded part. If this temperature increase occurred when the remainder of a fruit was at about the optimal temperature for lycopene formation it would be sufficient to prevent lycopene formation. Whether such temperature conditions occur in tomato fruit grown under glass in the United Kingdom is not known, since the essential preliminary (as judged by a close study of the literature) to work on blotchy ripening, namely a study of fruit tissue temperature under glass in relation to pigmentation, has never been carried out in this country.

The possible inter-relation of blotchy ripening and tomato virus diseases has been studied by Selman and he has stated that early infection with tomato mosaic virus "induced small, although non-significant, increases in the percentage of blotchy fruit produced." Gigante also studied the symptoms of blotchy ripening in relation to tomato virus diseases and stated that "neither external nor internal symptoms correspond exactly to any of the characteristic tomato viruses which extend their effect to the fruit, thus a virus cause can be excluded." He went on to say that blotchy ripening was "in some respects analogous to a disorder of tomatoes attacked by a particular virus described by me in 1936. But in the case of the virus the green and yellowish patches were more marked and frequently showed clear-cut margins and regular shapes. In this virus disease, too, there is browning of the vascular strands, but here the necrosis involves the xylem and phloem elements as well as the parenchyma. Phloem necrosis is particularly evident and occurs in the stem also."

A certain amount of work on the changes in chemical composition of tomato fruit during ripening has been carried out, as well as some work on the changes occurring in abnormally ripening fruit. This aspect of blotchy ripening has recently been considered in a previous Annual Report.

With the exception of the literature referring to these associated changes in chemical composition of abnormally ripening fruit, the following list of references to work on blotchy ripening is believed to be complete.

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5. 1956 OBSERVATIONS ON FRUIT PIGMENTATION IN THE POTENTATE VARIETY OF TOMATO

by

A. J. COOPER

From detailed work carried out during 1954 and 1955 it became apparent that abnormalities in the pigmentation of ripe fruit of Potentate were so varied in form that the term "blotchy ripening" as defined and used by various writers was too vague to be of useful application. More precise definitions of the abnormalities that occur were made and a detailed classification of pigmentation abnormalities was drawn up. The results of this work are awaiting publication.

The classification scheme developed was essentially complex because the types of abnormal pigmentation occurring were numerous and their inter-relations still unknown. To facilitate work on a larger scale a simplified fruit grading scheme was developed from this detailed classification and determined on the basis of the frequency of occurrence of the different types of abnormal pigmentation so that the error introduced by making the definitions less exact and more embracing was minimised.

Six grades were defined as follows:

Grade UC: uniformly coloured red fruit.
Grade A: red fruit with a distinct green area (or areas) around the calyx.
Grade B: red fruit with a distinct yellow area (or areas).
Grade C: red fruit with a distinct green area (or areas) in a position other than around the calyx.
Grade D: red fruit with a distinct unpigmented area (or areas) the colour of a wax candle.
Grade Z: all fruit that do not fall into the above grades.

This last grade contains mostly fruit that are obviously not uniformly coloured and yet do not show distinct areas of a colour other than red. The colouring of such fruit is usually a mixture of red, yellow and the waxy colour of unpigmented tissue, and the three colours shade into and out of each other so frequently and yet so gradually that it is not possible to classify them as Grade B or Grade D.

It is possible for more than one type of abnormal pigmentation to occur on the same fruit and where this happened the fruit was recorded as a combination of more than one grade — e.g., C/D.

Observations during 1956 were carried out on twenty single-stemmed plants, each plant being grown in the border of a vinery type house 6ft. distant from the next plant to avoid mutual shading, and no shading was applied to the glasshouse roof. Picking was carried out daily and the fruit was graded by the same recorder throughout the season.

Results

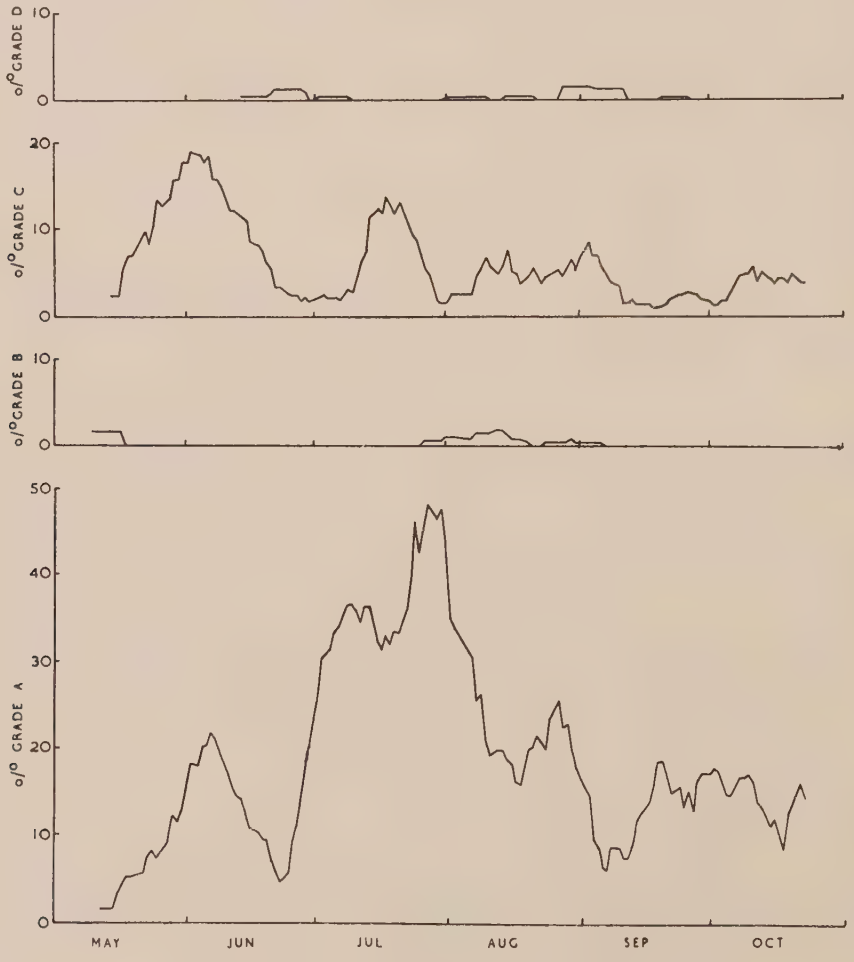

FIGURE 1. Relation between pigmentation abnormality and picking date in 1956.

In Figure 1 is shown the relationship between the four main types of abnormal pigmentation and the date of picking. The general trends have been illustrated by plotting the running means based on the data for seven consecutive pickings at one day intervals, i.e., each point on the curve was influenced by the data from the three days immediately preceding and succeeding it.

The amounts of fruit with yellow and unpigmented areas were very small relative to the amount of fruit with green areas. This may have been a seasonal characteristic as, in 1955, although the green type of abnormal pigmentation was still the most frequent, there was much more of the yellow type of abnormality. In 1956 the amount of Grade B and Grade D fruit occurring was so small that there was little evidence on which to evaluate the possibility of any relationship with the time of the year.

It can be seen from Figure 1 that during 1956 the percentage of fruit with green areas around the calyx (Grade A) increased from the commencement of picking to a maximum in late July and then declined, but that there were pronounced short term fluctuations.

The percentage of Grade C fruit in 1956 increased to a maximum in early June and then declined, and with this type of abnormal pigmentation there were also pronounced short term fluctuations.

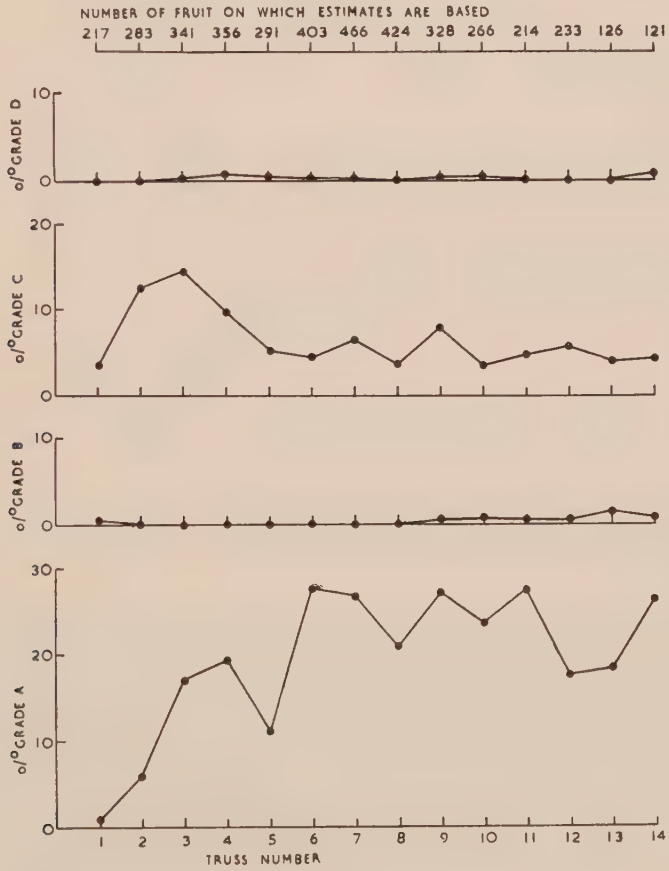
NUMBER OF FRUIT ON WHICH ESTIMATES ARE BASED
217 283 341 356 291 403 466 424 328 266 214 233 126 121
% GRADE D
% GRADE C
% GRADE B
% GRADE A
TRUSS NUMBER
1 2 3 4 5 6 7 8 9 10 11 12 13 14

FIGURE 2. Relation between pigmentation abnormality and truss position in 1956.

In Figure 2 is shown the percentage of each of the four grades that occurred in each truss, the trusses being numbered from the base of the plant upwards. Again the amount of Grade B and Grade D fruit was too small to evaluate the possibility of any relationship with the position of the trusses on the plant. It can be seen, however, that in 1956 the percentage of fruit with green areas around the calyx (Grade A) rose from a minimum in the first truss to a maximum in the sixth truss, and that the percentage occurring tended to remain at this high level in the succeeding trusses. The percentage of fruit with green areas *other* than around the calyx (Grade C) showed a different trend in relation to truss position. The percentage increased in 1956 from a low level in the first truss to a maximum in the third, it then decreased until the percentage in the fifth truss was again low and this low level was maintained in the succeeding trusses.

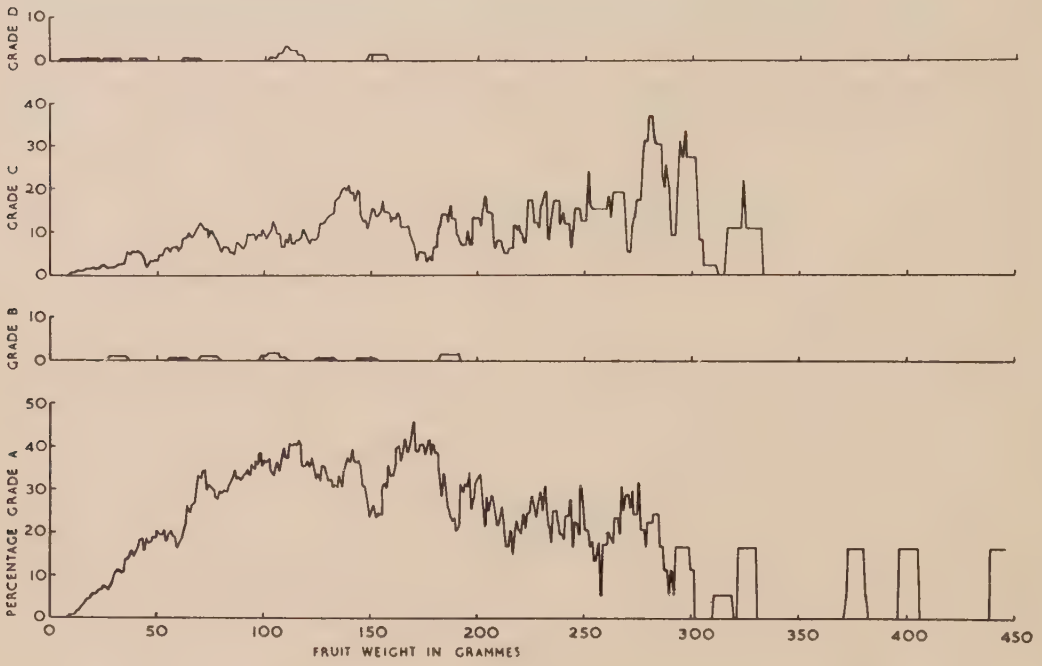

FIGURE 3. Relationship between pigmentation abnormality and fruit size in 1956.

The evidence in the 1956 data for the possible existence of a relationship between fruit size and abnormal pigmentation is shown in Figure 3, where the general trends are shown by plotting the running means based on the data for nine consecutive fruit weights at 1 gram class intervals. Again the amount of fruit in Grades B and D was too small to give any indication of the presence or absence of a relationship with fruit size. The percentage of fruit ripening with green areas around the calyx increased with increase in fruit size until the maximum occurrence of this Grade A fruit was reached between 110 and 180 grams. With further increase in fruit size above 180 grams there tended to be a decrease in the percentage Grade A fruit. The percentage of fruit occurring with green areas *other* than around the calyx (Grade C) increased continuously with an increase in fruit size, and there was no indication of an optimal fruit size for the maximal occurrence of the abnormality.

To summarise, it is possible to conclude that the existing definitions of blotchy ripening are too numerous and varied for the term to have a precise meaning. The proposed fruit grading scheme utilising six grades of pigmentation eliminates this lack of precision, and in 1956 its use demonstrated that in the one year there appeared to be marked seasonal differences between the two grades (A and C) of green mal-pigmentation, and that these two grades together contained the majority of the non-uniformly coloured fruit. It also demonstrated that there was a differing fruit size relationship for the two grades of green mal-pigmentation and also a difference in their incidence in relation to truss position.

In conclusion it must be emphasized that the above observations refer only to the conditions obtaining in 1956. The apparent trends and relationships may well be shown to be fallacious when considered over several years.

III. CHEMISTRY

1. THE COMPOSITION OF TOMATO FRUIT IN RELATION TO VARIETY, STATE OF RIPENESS AND FRUIT QUALITY

by

D. M. MASSEY & G. W. WINSOR

The results which follow form a progress report on various aspects of an investigation of the composition of tomato fruit. The present results refer mainly to the expressed sap of the fruit, and are regarded as a preliminary stage leading up to more detailed biochemical investigations. At the time of drafting this report statistical examination of some sections of the results had not been completed, and further experimental work will also be required before some of the tentative conclusions can be fully established.

The composition of sap expressed from fruit of different varieties

Preliminary data on the composition of sap expressed from fruit of ten varieties of tomato were presented in the Annual Report for 1955 (2). Though limited to only three sampling dates, the results showed a number of interesting features. Thus certain differences between varieties were apparent, samples of fruit of variety L.M.R.1, for example, having a particularly high content of acids, sugars and nitrogenous compounds in the sap; seasonal trends in acidity and electrical conductivity of the sap were also indicated.

Work on the composition of different varieties of tomato was continued during 1956, including studies of seven varieties from houses F1 and F2, and of nine varieties from houses G1 and G2. The fruit used in these investigations was of the best quality available, a combined sample being obtained from four plots of each variety. Houses F1 and F2 were planted relatively early (13/1/56), the seed being sown in October 1955. Houses G1 and G2 were planted later (6/3/56) and cropped until October. Fruit from F block was sampled once in May, twice in June and three times in July; samples from G block were examined once in June, three times in July and once each in August and September.

Analytical results for percentage dry matter in the fruit and for soluble solids, sugars, titratable acidity and nitrogen in the expressed sap of fruit from F block are shown in Tables I—V; corresponding data for G block are presented in Tables VI—X. Significant differences between means for varieties and for sampling dates are given below each table.

TABLE I

Percentage dry matter in the fruit of seven varieties of tomato (F block, 1956)

Date of sampling	1 Delicious	2 Down's Seedling	3 E.S.5	4 Kondine Red	5 Potentate	6 Potential	7 Up-to-date	Average
28th May ..	6.72	5.79	5.88	6.50	6.44	6.13	6.98	6.35
4th June ..	6.91	6.53	6.93	6.21	6.63	5.82	6.78	6.54
27th June ..	7.27	6.09	6.28	6.21	6.44	6.25	7.35	6.56
11th July ..	7.86	5.95	6.91	6.94	6.76	6.49	7.67	6.94
16th July ..	7.82	6.47	7.01	7.03	7.55	6.73	8.06	7.24
26th July ..	8.42	6.84	7.17	7.56	7.75	6.86	7.76	7.48
Average ..	7.50	6.28	6.70	6.74	6.93	6.38	7.43	

Significant differences at P=0.05: Variety 0.32; date of sampling 0.30.
„ „ „ P=0.01: „ 0.43; „ „ 0.40.

TABLE II

Total solids (g./100 ml.) in the expressed sap of seven varieties of tomato fruit (F block, 1956)

Date of sampling	1 Delicious	2 Down's Seedling	3 E.S.5	4 Kondine Red	5 Potentate	6 Potential	7 Up-to-date	Average
28th May ..	5.28	4.52	4.38	4.91	4.80	4.54	5.48	4.84
4th June ..	5.20	4.71	4.62	4.52	4.97	4.27	5.22	4.79
27th June ..	5.15	4.38	4.76	4.56	4.66	4.30	5.44	4.75
11th July ..	5.89	4.83	5.36	5.30	4.80	4.90	5.99	5.30
16th July ..	5.90	4.62	5.12	5.43	5.87	4.95	6.16	5.44
26th July ..	6.16	4.82	5.26	5.49	5.80	5.12	6.04	5.53
Average ..	5.60	4.65	4.92	5.04	5.15	4.68	5.72	

Significant differences at P=0.05: Variety 0.25; date of sampling 0.23.
„ „ „ P=0.01: „ 0.33; „ „ 0.31.

TABLE III

Reducing sugars (g./100 ml.) in the expressed sap of seven varieties of tomato fruit (F block, 1956)

Date of sampling	1 Delicious	2 Down's Seedling	3 E.S.5	4 Kondine Red	5 Potentate	6 Potential	7 Up-to-date	Average
28th May ..	3.44	2.84	2.83	3.17	3.28	3.03	3.52	3.16
4th June ..	3.45	3.15	2.98	2.85	3.17	2.86	3.45	3.13
27th June ..	3.44	2.88	3.21	2.96	3.09	2.99	3.63	3.17
11th July ..	3.79	3.09	3.58	3.44	3.31	3.29	3.96	3.49
16th July ..	3.92	2.95	3.38	3.54	4.13	3.36	4.11	3.63
26th July ..	4.10	3.20	3.51	3.51	4.07	3.43	4.09	3.70
Average ..	3.69	3.02	3.25	3.25	3.51	3.16	3.79	

Significant differences at P=0.05: Variety 0.20; date of sampling 0.18.
„ „ „ P=0.01: „ 0.27; „ „ 0.25.

TABLE IV

The titratable acidity (ml. N/10 sodium hydroxide per 10 ml.) of the expressed sap of seven varieties of tomato fruit (F block, 1956)

Date of sampling	1 Delicious	2 Down's Seedling	3 E.S.5	4 Kondine Red	5 Potentate	6 Potential	7 Up-to-date	Average
28th May ..	9.72	7.33	7.99	8.46	7.56	6.89	8.95	8.13
4th June ..	10.66	7.95	9.37	9.13	9.65	7.30	9.24	9.04
27th June ..	11.11	8.00	9.28	9.25	8.12	7.02	9.27	8.86
11th July ..	12.02	8.82	9.07	10.00	8.31	8.34	9.95	9.50
16th July ..	11.46	8.62	9.53	10.43	9.27	8.14	9.72	9.60
26th July ..	12.54	8.31	9.39	10.94	8.64	8.55	9.15	9.65
Average ..	11.25	8.17	9.11	9.70	8.59	7.71	9.38	

Significant differences at P=0.05: Variety 0.55; date of sampling 0.51.
„ „ „ P=0.01: „ 0.74; „ „ 0.68.

TABLE V

The nitrogen content (mg. nitrogen per 100 ml.) of the expressed sap of seven varieties of tomato fruit (F block, 1956)

Date of sampling	1 Delicious	2 Down's Seedling	3 E.S.5	4 Kondine Red	5 Potentate	6 Potential	7 Up-to-date	Average
28th May ..	81.5	97.1	79.0	106.1	85.5	97.8	115.5	94.6
4th June ..	88.3	81.3	85.4	83.7	90.2	75.3	108.8	87.6
27th June ..	100.5	79.9	88.0	96.4	84.4	88.9	123.3	94.5
11th July ..	110.7	88.7	91.9	99.4	86.9	90.3	117.7	97.9
16th July ..	97.6	93.5	101.4	113.1	103.5	91.5	128.5	104.2
26th July ..	134.1	98.6	124.4	143.1	109.6	114.8	132.9	122.5
Average ..	102.1	89.9	95.0	107.0	93.4	93.1	121.1	

Significant differences at P=0.05: Variety 9.6; date of sampling 8.9.
„ „ „ P=0.01: „ 13.0; „ „ 12.0.

Results for F block

The analytical results for fruit from F block are of interest in that the percentage of dry matter in the fruit and the content of soluble solids in the sap were particularly high throughout the season; inclusion of varieties such as Delicious and Up-to-date also served to widen the range of analytical values obtained as compared with those for G block.

The percentage of dry matter in the fruit (Table I) tended to increase as the season progressed, and particularly high values were recorded on the last date of sampling (July). Significant differences were also found between the dry matter content of fruit from different varieties, Delicious and Up-to-date showing particularly high values and Down's Seedling and Potential being the lowest of the group in this respect.

The content of soluble solids in the sap (Table II) increased at the end of June. Significant differences were also found between fruit of the different varieties; thus, as already described for percentage dry matter in the fruit, Delicious and Up-to-date showed the highest and Down's Seedling and Potential the lowest values of the group.

The sugar content (Table III) of the sap showed the same trends as already described for total soluble solids in the sap, and need not be described separately. It may be noted that the sugars form by far the largest group of sap constituents, in general amounting to 60% or more of the total solids present.

The titratable acidity of the sap (Table IV) tended to rise as the season progressed. Differences between mean values for the varieties were particularly marked, ranging from 7.7 ml. N/10 alkali per 10 ml. of sap for Potential up to 11.3 for Delicious. The values for Delicious were, indeed, outstandingly high; the figure of 12.54 obtained at the last date of sampling (July) is the highest yet encountered for whole fruit in the course of these investigations. It is also of interest that the second highest value recorded in these studies was obtained in 1955 with fruit of this same variety.

The nitrogen content of the sap (Table V) in general increased with sampling date, and significant differences between varieties were again demonstrated. The highest values were found in Up-to-date and Kondine Red, the lowest in Down's Seedling followed by Potential and Potentate.

TABLE VI

Percentage dry matter in the fruit of different varieties of tomato fruit (G block, 1956)

Date of sampling	1 Plumpton King	3 Baby Lea	5 Craig × Potentate	7 Kondine Red	11 Ailsa Craig	12 Vagabond	14 Poultonian	19 Potentate I	20 Potentate II	21 Potential	22 Potentate III	Average
19th June ..	5.59	5.34	5.23	5.60	5.75	5.51	4.97	5.21	5.32	5.83	5.14	5.41
3rd July ..	5.61	5.33	5.47	5.71	5.30	5.83	5.26	5.38	5.32	5.73	5.46	5.49
17th July ..	5.61	5.37	5.37	5.47	5.70	5.81	5.34	5.49	5.46	5.73	5.62	5.54
31st July ..	6.04	5.47	5.72	5.75	5.58	5.86	5.65	5.73	5.58	5.74	5.70	5.71
16th August	5.62	5.30	5.88	5.77	6.10	5.76	5.58	5.18	5.27	5.79	5.85	5.65
6th Sept. ..	5.61	5.51	5.54	5.86	5.73	6.14	5.84	5.75	5.62	5.72	5.87	5.74
Average ..	5.68	5.39	5.54	5.69	5.69	5.82	5.44	5.46	5.43	5.76	5.61	

Significant differences at P=0.05: Variety 0.20; date of sampling 0.15.
„ „ „ P=0.01: „ 0.26; „ „ 0.19.

TABLE VII

Total solids (g./100 ml.) in the expressed sap of different varieties of tomato fruit (G block, 1956)

Date of sampling	1 Plumpton King	3 Baby Lea	5 Craig × Potentate	7 Kondine Red	11 Ailsa Craig	12 Vagabond	14 Poultonian	19 Potentate I	20 Potentate II	21 Potential	22 Potentate III	Average
19th June ..	4.16	3.59	3.58	4.18	4.26	3.84	3.66	3.54	3.48	4.01	3.81	3.83
3rd July ..	4.14	3.84	4.00	4.22	4.01	4.35	3.78	3.94	3.66	4.11	3.98	4.00
17th July ..	4.33	3.90	4.04	4.18	4.53	4.47	4.01	4.08	4.05	4.33	4.04	4.18
31st July ..	4.48	4.10	4.10	4.01	4.28	4.38	4.16	4.20	4.07	4.20	4.24	4.20
16th August	4.28	4.02	4.09	4.33	4.51	4.49	4.17	4.24	4.02	4.32	4.22	4.24
6th Sept. ..	4.36	4.14	4.35	4.66	4.19	4.84	4.41	4.51	4.41	4.52	4.36	4.43
Average ..	4.29	3.93	4.03	4.26	4.30	4.40	4.03	4.09	3.95	4.25	4.11	

Significant differences at P=0.05: Variety 0.16; date of sampling 0.12.
„ „ „ P=0.01: „ 0.22; „ „ 0.16.

TABLE VIII

Reducing sugars (g./100 ml.) in the expressed sap of different varieties of tomato fruit (G block, 1956)

Date of sampling	1 Plumpton King	3 Baby Lea	5 Craig × Potentate	7 Kondine Red	11 Ailsa Craig	12 Vagabond	14 Poultonian	19 Potentate I	20 Potentate II	21 Potential	22 Potentate III	Average
19th June ..	2.52	2.16	1.80	2.26	2.68	2.45	2.41	2.11	2.18	2.41	2.37	2.30
3rd July ..	2.55	2.40	2.49	2.66	2.51	2.97	2.50	2.35	2.39	2.62	2.45	2.53
17th July ..	2.68	2.27	2.34	2.44	2.86	2.99	2.50	2.66	2.67	2.84	2.38	2.60
31st July ..	2.80	2.51	2.53	2.39	2.73	3.09	2.60	2.68	2.70	2.66	2.55	2.66
16th August	2.72	2.52	2.62	2.66	2.86	3.05	2.75	2.72	2.70	2.86	2.74	2.75
6th Sept. ..	2.57	2.44	2.74	2.64	2.41	3.33	2.93	2.90	2.96	2.71	2.65	2.75
Average ..	2.64	2.38	2.42	2.51	2.68	2.98	2.60	2.57	2.60	2.68	2.52	

Significant differences at P=0.05: Variety 0.18; date ol sampling 0.13.
„ „ „ P=0.01: „ 0.23; „ „ 0.17.

TABLE IX

The titratable acidity (ml. N/10 sodium hydroxide per 10 ml.) of the expressed sap of different varieties of tomato fruit (G block, 1956)

Date of sampling	1 Plumpton King	3 Baby Lea	5 Craig × Potentate	7 Kondine Red	11 Ailsa Craig	12 Vagabond	14 Poultonian	19 Potentate I	20 Potentate II	21 Potential	22 Potentate III	Average
19th June ..	8.92	6.92	6.99	9.79	8.58	6.99	6.27	6.70	5.97	8.36	7.03	7.50
3rd July ..	8.76	7.36	7.92	8.42	8.14	6.75	6.22	6.68	6.59	7.58	7.13	7.42
17th July ..	8.72	7.78	8.71	9.01	8.67	7.46	7.35	7.36	6.75	7.36	8.13	7.94
31st July ..	8.96	8.13	7.98	8.32	7.92	6.56	7.34	7.86	6.63	7.24	8.61	7.78
16th August	7.70	7.11	7.39	8.71	8.02	6.47	5.98	7.22	5.53	6.86	7.33	7.12
6th Sept. ..	7.77	7.21	6.73	8.82	8.70	7.30	6.16	6.62	5.61	7.45	7.27	7.24
Average ..	8.47	7.42	7.62	8.85	8.34	6.92	6.55	7.07	6.18	7.48	7.59	

Significant differences at P=0.05: Variety 0.54; date of sampling 0.40.
„ „ „ P=0.01: „ 0.71; „ „ 0.53.

TABLE X

The nitrogen content (mg. nitrogen per 100 ml.) of the expressed sap of different varieties of tomato fruit (G block, 1956)

Date of sampling	1 Plumpton King	3 Baby Lea	5 Craig × Potentate	7 Kondine Red	11 Ailsa Craig	12 Vagabond	14 Poultonian	19 Potentate I	20 Potentate II	21 Potential	22 Potentate III	Average
19th June ..	(77.3*)	71.4	71.9	83.8	78.5	66.2	68.3	57.3	56.7	89.1	60.7	71.0
3rd July ..	83.4	87.9	72.6	80.2	78.7	63.6	60.5	59.2	71.0	84.4	66.4	73.4
17th July ..	78.6	91.0	91.1	94.5	83.9	82.7	75.9	68.7	72.3	84.0	86.8	82.7
31st July ..	92.2	100.5	80.4	91.0	76.9	76.1	95.9	88.3	77.7	87.3	101.3	88.0
16th August	86.8	93.5	81.3	84.2	93.1	76.9	74.5	97.7	73.9	83.3	85.7	84.6
6th Sept. ..	112.5	93.5	97.2	108.1	119.9	79.3	73.2	73.9	72.6	106.6	88.5	93.2
Average ..	88.5	89.6	82.4	90.3	88.5	74.1	74.7	74.2	70.7	89.1	81.6	

Significant differences at P=0.05: Variety 10.2; date of sampling 7.5.
„ „ „ P=0.01: „ 13.6; „ „ 10.0.
* calculated "missing value".

Results for G block

The results for fruit from G block show considerably lower analytical values than those from F block. The range of numerical values is also considerably narrower, associated with the absence of varieties previously found to have a high proportion of sugars and acids in the expressed fruit juices (e.g. L.M.R.1, Radio, Delicious) and the inclusion of Potentate from three different sources together with related varieties such as Baby Lea and Poultonian.

The results for percentage dry matter in the fruit (Table VI) show a slight rise as the season progressed. Differences between mean values for the varieties, though in many cases statistically significant, are not particularly marked. Vagabond showed the highest mean value, and Baby Lea the lowest.

A seasonal increase in soluble solids in the sap (Table VII) was more clearly shown; Vagabond and Ailsa Craig gave the highest mean values, and Baby Lea and one strain of Potentate (No. 20) the lowest.

The sugar content of the sap increased as the season progressed (Table VIII); Vagabond and Baby Lea respectively gave the highest and lowest values of the group.

Values for the titratable acidity of the expressed sap (Table IX) were highest in July, and declined in August. Despite the absence of varieties having a particularly high acid content in the fruit, differences between varieties were again clearly demonstrated. Kondine Red gave the highest values, closely followed by Plumpton King and Ailsa Craig; the lowest values were found for one strain of Potentate (No. 20) and for Poultonian.

The nitrogen content of the sap (Table X) increased as the season progressed, and significant differences between varieties were found in many instances.

Discussion of results for fruit of different varieties

As shown in Tables I—X, significant differences in the composition of tomato fruit of many of the varieties tested can readily be established. It is, indeed, somewhat surprising that the composition of glasshouse tomatoes has not already attracted greater attention. Thus the sugar or acid content of a tomato is basically a more important characteristic than are minor irregularities in shape or even in pigmentation. Whilst such analytical tests are hardly adaptable to routine commercial grading, the results merit attention in assessing the characteristics of different varieties of tomato or the effects of different conditions of growth.

Of the varieties included in F block, Delicious and Up-to-date gave particularly high values throughout in all five tests now reported, whereas Down's Seedling and Potential gave relatively low values. The high acidity of the sap from fruit of the variety Delicious was among the most striking features of the results. Significant differences between varieties were also found for G block, though the overall ranges of values were markedly smaller. Thus, for example, Vagabond showed the highest values for percentage dry matter in the fruit and for sugars and total solids in the sap; in contrast, Baby Lea gave the lowest values in the same three tests.

The analytical results presented in Tables I—X also show, in general, increasingly high values as the season progressed. The magnitude of such seasonal changes varies from test to test, a marked increase occurring, for example, in the mean values for nitrogen content of the sap from fruit of varieties grown in G block, whereas the corresponding changes in the percentage dry matter in the fruit were proportionately smaller. The only exception found to this generalisation of the results in Tables I—X is found in the values for titratable acidity in G block; here the maximum values occurred in July and decreased in August and September. It may be noted that such data as were obtained in 1955 also indicated decreasing acidity in August and September.

Included in G block were plants of variety Potentate from three different sources Nos. 19, 20 and 22, and it is of interest to compare analytical results for these, as shown in Table XI. The values shown are the means for six sampling dates.

TABLE XI

Comparison of fruit of the variety Potentate raised from seed obtained from three different sources.

	19	20	22	Significant difference
Dry matter in fruit, %	5.46	5.43	5.61	0.20
Total solids in sap, g./100 ml.	4.09	3.95	4.11	0.16
Reducing sugars, g./100 ml.	2.57	2.60	2.52	0.18
Titratable acidity	7.07	6.18	7.59	0.54
Nitrogen, mg./100 ml.	74.2	70.7	81.6	10.0

Note.—The numbers 19, 20 and 22 were those assigned to the three strains of Potentate in the glasshouse trials. The results given are means for six sampling dates (G block, 1956).

No significant differences were found between the three strains of Potentate with regard to percentage dry matter and sugar in the sap. In the remaining tests no significant differences were found between No. 19 and No. 22, but No. 20 gave somewhat lower values than No. 22 for nitrogen and total solids in the sap, and significantly lower values than both No. 19 and No. 22 for titratable acidity. Compared with the differences frequently observed between different varieties, however, the three strains of Potentate showed considerable similarity, the most marked variation being in titratable acidity.

Arising from these and other results, three conclusions may be mentioned with regard to future studies. Firstly, it would seem that much interesting information could be obtained from a simplified scheme of analysis in which only titratable acidity, sugars and total solids were determined. The introduction, where possible, of relatively rapid physical techniques of measurement would also be advantageous in that larger numbers of samples could be examined. Lastly it is suggested that comparison of the fruit walls of different varieties, as distinct from the whole fruit, might well prove of interest, it being in the fruit walls that disorders such as blotchy ripening become apparent.

Changes in the composition of the expressed sap of tomato fruit during ripening

Analytical data for sap expressed from frozen whole tomato fruit at different stages of ripeness, and also for sap expressed from the fruit walls and for the free fruit juices, were presented in a previous report (2). It was concluded that the concentrations of sugar and of total soluble solids in the sap both increased with degree of ripeness from green to red for all parts of the fruit examined. The data obtained for the titratable acidity of the sap samples during 1955, however, appeared to show opposing trends in the fruit walls and in the free sap. In view of the more complex nature of the results for titratable acidity, more extensive analyses were accordingly made during 1956.

The results obtained in this section of the fruit investigations during 1956 include nine series of whole fruit samples, each containing either five or six different stages of ripeness from green to full redness, ten series of fruit walls and six series of free fruit juices. All samples were from fruit of the variety Potentate. The complete data are too extensive to be recorded fully in this report; results for ripening series containing five stages from green to red are given for total sap solids, sugars and titratable acidity in whole fruit, fruit walls and free juices in Tables XII to XIX.

TABLE XII

Total solids (g./100 ml.) in the expressed sap of whole tomato fruit at different stages of ripeness.

Date of Sampling	Stage of ripening				
	Green	Green-Yellow	Yellow-Orange	Orange-Red	Red
5th June	4.07	4.41	4.40	4.47	4.30
22nd June.. ..	4.25	4.63	4.49	4.61	4.62
4th July	4.23	4.86	4.74	4.88	4.96
18th July	4.56	5.23	5.57	5.20	5.30
21st August ..	4.38	4.95	5.08	5.23	5.19
Average	4.30	4.82	4.86	4.88	4.87

TABLE XIII

Reducing sugars (g./100 ml.) in the expressed sap of whole tomato fruit at different stages of ripeness

Date of Sampling	Stage of ripening				
	Green	Green-Yellow	Yellow-Orange	Orange-Red	Red
5th June	2.40	2.37	2.61	2.72	2.72
22nd June.. ..	2.78	3.19	3.02	3.34	3.08
4th July	2.69	3.23	3.29	3.23	3.47
18th July	2.97	3.58	3.68	3.46	3.45
21st August ..	2.73	3.43	3.49	3.59	3.69
Average	2.71	3.16	3.22	3.27	3.28

TABLE XIV

The titratable acidity of the expressed sap of whole tomato fruit at different stages of ripeness

Date of Sampling	Stage of ripening				
	Green	Green-Yellow	Yellow-Orange	Orange-Red	Red
5th June	8.51	9.44	9.29	8.11	7.03
22nd June.. ..	9.17	9.13	8.69	7.54	8.02
4th July	8.26	9.88	8.57	9.13	7.97
18th July	9.00	9.69	9.63	8.70	8.57
21st August ..	7.48	9.17	8.40	7.97	7.13
Average	8.48	9.46	8.92	8.29	7.74

The data for sap expressed from whole fruit in every case show a marked rise in both sugar and total sap solids accompanying the first appearance of yellow-orange colouration in the fruit walls (Tables XII and XIII). In general the results for sugar in the sap show some slight tendency to further increase until the red or orange-red stage was reached. The mean values for titratable acidity in the whole fruit show a rise from the green to the yellow-green stage, after which the acidity decreased markedly (Table XIV). The results for acidity in series containing fruit at six different stages of ripeness, not included in the Tables, show a similar trend, except for a single series of fruit of variety E.S.5; in the latter series the green fruit showed a high acidity which decreased subsequently as ripening proceeded.

TABLE XV

Total solids (g./100 ml.) in the expressed sap of tomato fruit walls at different stages of ripeness

Date of Sampling	Stage of ripening				
	Green	Green-Yellow	Yellow-Orange	Orange-Red	Red
26th June	4.01	4.21	4.46	4.51	4.70
18th July	4.61	5.16	5.28	4.94	5.35
24th Sept... ..	4.19	4.63	4.83	4.82	4.90
26th Sept... ..	4.13	4.43	4.65	4.32	4.42
8th Oct.	3.96	4.26	4.22	4.15	4.21
Average	4.18	4.54	4.69	4.55	4.72

TABLE XVI

Reducing sugars (g./100 ml.) in the expressed sap of tomato fruit walls at different stages of ripeness

Date of Sampling	Stage of ripening				
	Green	Green-Yellow	Yellow-Orange	Orange-Red	Red
26th June	2.99	3.18	3.41	3.37	3.47
18th July	3.27	3.75	3.88	3.50	3.85
24th Sept... ..	3.08	3.43	3.56	3.60	3.58
26th Sept... ..	3.00	3.04	3.50	3.24	3.21
8th Oct.	3.08	3.32	3.14	3.14	3.07
Average	3.09	3.34	3.50	3.37	3.44

TABLE XVII

The titratable acidity of the expressed sap of tomato fruit walls at different stages of ripeness

Date of Sampling	Stage of ripening				
	Green	Green-Yellow	Yellow-Orange	Orange-Red	Red
26th June	5.18	6.06	5.90	5.65	5.76
18th July	4.84	6.71	6.42	6.28	5.98
24th Sept... ..	3.91	5.20	4.90	4.89	5.22
26th Sept... ..	4.52	4.56	5.01	4.64	4.74
8th Oct.	4.14	4.51	4.54	4.59	4.64
Average	4.52	5.41	5.35	5.21	5.27

The results for sap solids and sugars in the fruit walls show a rather similar trend to those in the whole fruit, notably a well-defined rise with the first appearance of yellow-orange colouration (Tables XV and XVI). The data for titratable acidity, however, are markedly different from those for whole fruit, there being no consistent tendency for the acidity to decrease appreciably after the first appearance of colour. Thus, of the five series of samples in Table XVII, only one (18/7/56) showed a steady decrease in acidity after the first appearance of yellow-orange colour. In contrast, the series of fruit samples picked in October showed little variation apart from the usual increase

at the start of ripening. Furthermore, in one series of fruit samples containing six graded colour stages, not given in the Tables, the acidity rose steadily until the fifth (orange-red) stage and only decreased when the full red was reached. Increasing acidity of the fruit walls during ripening had already been noted in the two series examined in 1955 (2), and this trend in the 1955 samples was confirmed by analysis during 1956 of a further series of fruit walls preserved in the frozen state since the previous year.

TABLE XVIII

The sugar content (g./100 ml.) of the free juices of tomato fruit at different stages of ripeness

Date of Sampling	Stage of ripening				
	Green	Green-Yellow	Yellow-Orange	Orange-Red	Red
26th June	2.21	2.74	2.88	2.92	2.84
18th July	2.14	2.52	3.00	2.75	3.09
8th Oct.	2.21	2.64	2.72	2.58	2.48
	1 Green	2	3	4	5	6 Red
21st Aug... ..	2.03	2.42	2.57	2.56	2.98	3.25
29th Aug. ..	2.19	2.81	2.73	3.18	3.21	3.42
16th Oct.	2.17	2.43	2.47	2.52	2.65	3.05

TABLE XIX

The titratable acidity of the free juices of tomato fruit at different stages of ripeness

Date of Sampling	Stage of ripening				
	Green	Green-Yellow	Yellow-Orange	Orange-Red	Red
26th June	18.6	16.8	15.7	14.5	13.7
18th July	18.3	17.6	17.1	13.9	12.2
8th Oct.	16.5	13.5	13.0	12.0	11.2
	1 Green	2	3	4	5	6 Red
21st Aug.	16.0	18.8	17.8	16.2	15.2	11.9
29th Aug.	11.3	17.2	15.2	13.4	12.3	11.4
16th Oct.	16.2	15.3	14.3	13.0	11.4	10.2

In order to illustrate the trends observed in free fruit juices, the results for fruit samples graded into both five and six stages of ripeness are included in Tables XVIII and XIX; data for sap solids are incomplete and have been omitted. The sugar content of the sap (Table XVIII) in every case increased with the first yellow colouring of the fruit, and in five of the six series showed a general upward trend throughout ripening. The acidity of the free juices decreased markedly from green to red in four of the six ripening series, and from first yellow colouration to full ripeness in the remaining two series. As compared with the sap expressed from frozen fruit walls, the sugar content of the free juices is relatively low and the acidity particularly high.

Of the tests referred to in Tables XII—XIX, the acidity of sap expressed from the fruit walls has shown the least consistent trend among the various ripening series. The only two series of fruit walls examined in 1955 both showed values for acidity increasing with ripeness, this trend being confirmed on samples preserved from 1955 for analysis during 1956. Samples of fruit walls taken in 1956 showed values for acidity in different series both rising and falling during ripening, as well as series in which relatively little change occurred throughout. In view of the differences in acidity previously found between normal and blotchy fruit and the obvious association of the latter disorder with the external fruit walls, further work on the acids of tomato fruit appears to be necessary.

It is of interest to note the relatively marked changes in sugars and total solids in the expressed sap between the mature green fruit and samples showing the first yellow or orange colouration, in contrast to the less marked changes subsequently. As stated in the report for 1955, fruit classified in the tables as of stage 2 (green-yellow) showed green as the predominant colour. Attention is thus drawn to the very early stages of ripening, and to the chemical changes which precede the more obvious changes in colouration.

Finally it may be noted that the original object in studying changes in the composition of expressed sap during ripening was to relate such changes to the differences observed between normal and blotchy whole fruit, and to differences between variously coloured portions of the walls of blotchy fruit. Such comparisons are complicated by the difficulty of assigning the green or yellow-green areas of blotchy fruit to any one particular stage in the development of normal tomato fruit. The blotchy areas of the walls of tomato fruit sometimes appear to resemble green fruit (stage 1) in both colour and texture, but more frequently are markedly softer and more yellow-green in colour. In view of the marked changes in composition associated with these early stages of ripening, some uncertainty thus arises in attempting to relate the composition of blotchy fruit to the normal stages of ripening. If, however, we assume that the blotchy areas are somewhat riper than stage 1 in the Tables, and that the orange-red areas of the blotchy fruit approximate to stage 4, several tentative conclusions may be drawn. Referring firstly to blotchy whole fruit, if the blotchy areas resulted merely from delayed ripening of the fruit and orange-red areas are regarded as normal, then the overall composition of the expressed sap should be intermediate between stages 2 and 4 in the Tables, depending on the proportion of blotchy and normal fruit walls in the sample. The lower content of sugars and total solids in the sap expressed from blotchy as compared with normal tomato fruit is indeed consistent with the presence of green-yellow areas of apparently unripened fruit walls; that the presence of such areas of unripe tissue would be sufficient to account for the magnitude of the observed differences between normal and blotchy fruit is, however, less certain. In contrast to the results for sugars and sap solids, the lower acidity of blotchy fruit as compared with uniformly coloured fruit appears to be inconsistent with the trends noted in graded series of whole fruit during 1956. Thus sap from blotchy fruit has a lower acidity than that of normal orange-red fruit, yet the titratable acidity of uniformly coloured fruit decreases from the first appearance of yellow colouration onwards. The conclusion that the lower acidity of blotchy as compared with normal fruit cannot be attributed merely to the presence of patches of less ripe tissue is supported by the fact that the mean value for titratable acidity in blotchy fruit of variety Potentate during 1956 was lower than any value obtained for whole fruit at any stage of ripeness from green to red in the ripening series of the same year.

The composition of normal, blotchy and waxy fruit

A comparison of the composition of sap expressed from normal and blotchy fruit was given in the Annual Report for 1954 (1). Significant differences were established between the content of dry matter in normal and blotchy fruit, and between the total solids, sugar and nitrogen content

and the acidity of the sap samples. The fruit samples, all of variety Potentate, were obtained from sixteen nurseries in the Lea Valley.

During 1956 a further series of twelve paired samples of normal and blotchy fruit of variety Potentate was examined, all the fruit used being grown at the Glasshouse Crops Research Institute. Without reviewing the results in detail, it may be said that significantly higher values were again found for percentage dry matter and for total solids, sugars, nitrogenous compounds and acidity in the sap of normal than in that of blotchy fruit. In addition, the results for 1956 indicated significantly higher contents of potassium and ash, and somewhat higher values for electrical conductivity, in the sap of normal fruit. The results for 1954 were thus confirmed and extended, and a combined account of the work will be prepared for publication elsewhere.

TABLE XX

The composition of normal, blotchy and waxy tomato fruit

	Sample taken 4/7/56			Sample taken 16/7/56		
	Normal	Blotchy	Waxy	Normal	Blotchy	Waxy
Dry matter in fruit, % ..	5.64	5.06	5.11	5.99	5.66	4.76
Total solids in sap, g./100 ml.	4.21	3.60	3.46	4.50	4.18	3.02
Reducing sugars, g./100 ml. ..	2.69	2.32	1.95	2.99	2.78	1.80
Titratable acidity	7.20	6.04	5.42	8.20	6.75	4.63
Nitrogen, mg./100 ml. ..	82.1	74.6	48.3	76.1	81.2	65.3

The same tests as have been used to establish differences in the composition of normal and blotchy fruit were also applied during 1954, 1955 and 1956 to a more limited number of samples of fruit showing "waxy" or translucent areas in the outer walls. The results of two such series of tests are shown in Table XX. The general conclusion to be drawn from these and similar sets of data is that the content of total solids, sugars, nitrogenous compounds and acids in the expressed sap, already shown to be lower in blotchy than in normal fruit, is even lower in "waxy" fruit. The data in Table XX for total solids, sugars and acids in the sap indeed show a particularly consistent gradation from normal to waxy fruit, the values for "waxy" fruit being amongst the lowest analytical values encountered in the course of the present investigations. The results shown were taken at random from the records, and include one minor anomaly in that the nitrogen content of the blotchy fruit collected on 16th July, 1956, was slightly higher than that of the uniformly coloured sample; the general trend of the results for soluble nitrogen since 1954 is, however, similar to that shown for the samples dated 4th July, 1956. Elucidation of the mechanism and primary causes of the disorders will be necessary before the relationship between blotchy and waxy fruit can be established; the possibility that waxy patch is a more severe form of blotchy ripening, however, is in no way inconsistent with the results of Table XX.

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2. CHROMATOGRAPHIC EXAMINATION OF SOME CONSTITUENTS OF TOMATO FRUIT, WITH PARTICULAR REFERENCE TO THE CARBOHYDRATES

by

J. N. DAVIES

Investigations of the composition of tomato fruit in relation to fruit quality, initiated during 1954, were at first largely confined to the relatively rapid routine determination of various components of the expressed sap, including the sap solids, sugars, acids, nitrogenous compounds and various inorganic constituents (2, 3, 4). As an extension of this preliminary work, a more detailed and fundamental investigation of some of the organic constituents of glasshouse crops has since been undertaken.

The carbohydrates of tomato fruit have been selected for initial study. The free sugars present in the expressed sap of fresh and frozen fruit, and in 80% ethyl alcohol extracts, have been examined by paper chromatography. Clearing or de-ionizing the extracts prior to chromatography appears to be unnecessary; such treatments produced chromatograms similar to those of the original materials.

Qualitative examination of many samples, ranging from fruit at various stages of ripeness to different varieties and qualities revealed substances indistinguishable chromatographically from fructose and glucose. No other free sugars have so far been detected in appreciable quantities. In one instance, after concentration of an alcoholic extract of ripe fruit (variety: Potentate) to a syrup, a trace of a sugar tentatively identified as sucrose was detected. Although this still lacks confirmation in other samples, it is in agreement with American workers who found traces of sucrose and a ketoheptose, along with glucose and fructose (5).

The possibility of the quantitative determination of glucose and fructose in tomato fruit is being examined. Some difficulty is, however, being experienced in obtaining on the paper chromatogram the degree of separation of glucose and fructose required for quantitative studies. Elution of known quantities of pure sugars from the paper, and their subsequent determination, have given encouraging results. The search for a suitable solvent is being continued.

The fraction of tomato fruit insoluble in 80% ethyl alcohol is also being studied. This material, which is presumed to be principally polysaccharides and proteins, constitutes about 2 — 2.5% of the fresh weight. Samples of the alcohol-insoluble material of ripe Potentate fruit have been hydrolysed with N-sulphuric acid and 1% oxalic acid. Paper chromatographic examination of the sulphuric acid hydrolysate, after neutralization and concentration, revealed sugars indistinguishable from arabinose, galactose and xylose, together with a trace of glucose. Only arabinose and a trace of glucose were detected in the oxalic acid hydrolysate. Possible methods for fractionation of the alcohol-insoluble constituents of tomato fruit are being examined, including techniques previously used elsewhere for pomaceous fruits (1).

A preliminary chromatographic examination of the organic acids present in 80% ethyl alcohol extracts of tomato fruit has shown the presence of citric and malic acids, together with traces of two other acids as yet unidentified.

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3. THE COMPOSITION OF TOMATO FOLIAGE FROM BLOCKS B AND C DURING 1955, AND ITS RELATION TO CROP YIELDS

by

G. W. WINSOR & J. N. DAVIES

The programme of analytical work undertaken in connection with calibration trials in Blocks B and C of the trial glasshouses, which was instituted by the Research Sub-Committee, has been continued. Both soil and tissue samples from 448 plots in houses B1–4 and C1–4 were taken during 1955; a further set of soil samples was obtained from Block B in 1956, Block C having been allocated to other experiments in the spring of that year. Analyses of the 1955 soil samples were not completed until early in 1957 and will form the subject of a later report.

In the present report is presented a summary of the analytical results for samples of leaf tissue taken in 1955, the variety being E.S.5. The leaf samples were taken between August 2nd and August 17th, 1955, and analysed during the following winter; an earlier date of sampling would have been preferable, but it was not possible to start until drying ovens for the leaf samples had been installed.

Sampling and analysis

Each of the houses contained 56 plots, the numbering and layout of which were described in a previous report (2). Plots 1 and 56 consisted of three single rows (12 plants) and plots 28 and 29 of one row (4 plants); all other plots consisted of two rows of plants (8 plants). The twelfth leaf below the growing point was removed from each plant and taken immediately to the laboratory; there the leaves were dried for 24 hours in a forced-draught oven at 80°C. The leaf samples were then crushed and stored in screw-top bottles prior to analysis.

Determinations of nitrogen, phosphate and potash were made by a wet-digestion procedure similar to that described by Cavell (1). Phosphate was determined colorimetrically, and potash with a flame photometer. The results are expressed as percentages of oven-dry tissue.

Data for crop yields from the 448 plots were obtained by the crop recorders, whose co-operation throughout is gratefully acknowledged.

Results

The full data for the 448 plots are too extensive to be reported here, but will be submitted elsewhere for more detailed statistical examination. The range of values for each house, for B and for C blocks, and for all eight houses combined, are given in Table I, together with the corresponding mean values. Coefficients of variation are recorded in Table II.

The values for nitrogen, phosphate, potash and crop yield all show considerable variability. The values for potash are, moreover, extremely low throughout, while those for nitrogen are below average. In contrast, the phosphate content of the leaves is in many cases somewhat higher than is normally encountered, despite a particularly low level of available phosphate in the soil.

A preliminary analysis of variance shows no significant differences between mean values for the nitrogen content of leaves from houses B1–4, C1 and C2. Mean values for nitrogen content in houses C3 and C4, while not significantly different from each other, are significantly lower than those in the other houses. Mean values for phosphate in leaf samples from individual houses in C block do not differ significantly; values for the four houses in B block are, however, not only significantly different from each other, but are also significantly higher than

those for C block. With regard to potash in the leaves and crop yields, differences between mean values for individual houses greater than 0.10% and 0.3 lb. per plant respectively are significant. In general, house means for potash and crop yield in B block are significantly higher than those for C block.

TABLE I

Summary of analytical data for tomato leaves from Houses B1—4, C1—4, in 1955 together with the crop yields

House	Nitrogen (% N)		Phosphate (% P_2O_5)		Potash (% K_2O)		Crop Yield (lb./plant)	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean
B 1	1.61—2.33	1.95	0.54—1.26	0.89	0.43—1.64	0.85	6.9—11.8	9.0
B 2	1.41—2.43	2.01	0.55—1.22	0.79	0.67—1.97	1.10	6.8—11.1	8.2
B 3	1.52—2.36	1.96	0.36—1.20	0.73	0.49—1.79	1.00	7.1— 9.7	8.3
B 4	1.61—2.95	2.04	0.45—1.36	0.85	0.57—2.37	1.19	6.7—11.4	8.6
C 1	1.56—2.60	2.00	0.44—0.99	0.67	0.55—1.46	0.89	5.6—10.3	7.5
C 2	1.48—2.76	1.99	0.40—1.09	0.66	0.48—1.41	0.78	4.3— 8.6	6.1
C 3	1.39—2.15	1.70	0.47—0.86	0.67	0.46—1.28	0.68	4.9— 9.0	7.2
C 4	1.20—2.45	1.62	0.47—1.19	0.69	0.36—1.29	0.64	5.4—11.0	6.8
B1—B4	1.41—2.95	1.99	0.36—1.36	0.81	0.43—2.37	1.03	6.7—11.8	8.5
C1—C4	1.20—2.76	1.83	0.40—1.19	0.67	0.36—1.46	0.75	4.3—11.0	6.9
B1—C4	1.20—2.95	1.91	0.36—1.36	0.74	0.36—2.37	0.89	4.3—11.8	7.7

Note.—All plants were of the variety E.S.5. The results for nitrogen, phosphate and potash are expressed on the basis of oven-dry tissue.

TABLE II

Coefficients of variation for nitrogen, phosphate and potash in leaf samples from Houses B1—4, C1—4 (1955), and also for crop yield

House	Nitrogen	Phosphate	Potash	Crop Yield
B 1	8.96	17.05	30.88	9.78
B 2	9.91	19.53	33.20	10.62
B 3	10.36	22.32	28.41	8.45
B 4	15.38	20.12	32.66	12.16
C 1	12.62	18.28	20.91	13.50
C 2	15.47	21.07	25.03	15.31
C 3	11.56	15.66	23.22	11.10
C 4	17.23	17.58	27.57	12.28

Correlations between crop yield and tissue analysis

Correlation coefficients relating crop yield and the results of leaf analyses are presented in Table III. One house (B3) in B block and another in C block (C1) showed significant (positive) correlations between crop yield and the nitrogen content of the leaf samples. A similar relationship holds for B and C block as a whole but not for the two blocks individually.

TABLE III

Correlation coefficients relating tissue analyses and crop yields (1955)

House	No. of Plots	Nitrogen	Phosphate	Potash
B 1	56	0.062	−0.284*	0.443***
B 2	56	0.054	−0.128	0.146
B 3	56	0.308*	0.325*	0.141
B 4	56	−0.177	0.061	0.053
C 1	56	0.292*	0.028	0.510***
C 2	56	0.181	−0.334*	0.320*
C 3	56	0.144	−0.448***	0.374**
C 4	56	0.084	−0.265*	0.510***
B1—B4	224	−0.011	0.090	0.085
C1—C4	224	0.091	−0.102	0.378***
B1—C4	448	0.219***	0.245***	0.416***

*P=0.05; **P=0.01; ***P=0.001.

Significant negative correlations were obtained between yields and the phosphorus content of leaf samples from houses B1, C2, C3 and C4. Despite the extremely low phosphate content of the soil, the phosphorus content of these leaf samples, taken during August, would not be regarded as in any way a limiting factor. We are inclined to view these negative correlations between crop yield and phosphorus content of the leaves as showing accumulation of the latter element where growth and cropping were retarded by other factors. In this connection it is of interest to note that the four houses for which significant negative correlations between yield and phosphorus content were found, each showed significant positive correlations with potassium in the tissue, levels of the latter element being very low throughout, and probably constituting the limiting factor in the later stages of growth. The situation with regard to phosphorus is, however, complicated by the existence of a significant positive correlation with yield in house B3; this may indicate a direct effect of phosphate deficiency, and is referred to again at the end of the section.

In all four houses of C block, and also in house B1, the potassium content of the leaves was significantly and positively correlated with crop yield, and the correlation remains highly significant for C block as a whole. In this connection it is of interest that only one house (B1) showed a significant correlation between "available" potash in the soil samples of 1954 and the crop yields for that year.

Since this work was done considerable further information has now been obtained concerning the very low phosphate content of our soil, an account of which will be presented in a subsequent report. It now appears that, despite the adequate or even high levels of phosphorus in leaf samples taken from fairly mature tomato plants during August, the extremely low content of available phosphate in this soil had a marked effect on plant growth, particularly in the early stages, and that this effect was unevenly distributed over the site, being more noticeable in parts of B block than elsewhere.

To summarise the conclusions based on correlations between crop yields and tissue analyses, together with other observations relating to B and C blocks:—

(1) Five out of eight houses (B1, C1–4) showed significant positive correlations between crop yield and potash content, generally accompanied by significant negative correlations between yield and phosphate content.

(2) Of the remaining three houses, all located in B block, two (B2 and B4) showed no significant correlation between yield and tissue analyses whatsoever, whilst house B3 gave the only significant positive correlation with phosphate content encountered during 1955.

(3) Values for the phosphate content of these relatively mature plants are likely to have given a very incomplete picture of the effects of this element in the trials; phosphorus deficiency may well have been the limiting factor in the early stages of growth.

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4. UREA-FORMALDEHYDE COMPOUNDS AS NITROGENOUS FERTILIZERS

by

M. I. E. LONG & G. W. WINSOR

In previous Reports (6, 7, 8) the properties of nitrogenous compounds prepared by reaction of urea with formaldehyde under various conditions were described. In particular the influence of the initial ratio of urea to formaldehyde and of the *p*H of the reaction mixture was clearly established, and additional information obtained on the temperature and duration of reaction; the value of preliminary reaction in alkaline solution prior to acidification was also examined. The urea-formaldehyde samples prepared under acid conditions appear to be very similar to those described by workers in America, and probably include materials of the types now becoming available commercially.

As a further line of approach in the development of urea-formaldehyde products as nitrogenous fertilizers, some urea-formaldehyde compounds have since been isolated in relatively pure state for laboratory tests on their rates of decomposition in soil, and also in less purified form for glasshouse trials with tomato plants.

Preparation of some urea-formaldehyde compounds

Monomethylol urea (NH_2. CO. NH. CH_2.OH) was prepared by the method of de Jong and de Jonge (4) and recrystallized from 80% alcohol.

Dimethylol urea ($HOCH_2.NH.CO.NH.CH_2OH$) was finally prepared as described by Baly and Baly (1), several other methods having proved unsatisfactory. Despite the instability of this compound, the analytical values obtained for nitrogen and for formaldehyde equivalent were in close agreement with those calculated from the formula (7).

Methylene diurea ($NH_2.CO.NH.CH_2.NH.CO.NH_2$) was prepared as described by Kadowaki (5) and recrystallized from water.

Dimethylene triurea was prepared by reaction of dimethylol urea with an excess of urea; analytical figures for total nitrogen and formaldehyde equivalent were in agreement with theory, and only a trace (less than 0.1%) of formaldehyde was present in the form of methylol groups (7).

Attempts to prepare trimethylene tetraurea were unsuccessful, but alternative methods of preparation are still being examined.

A product considered to consist very largely of tetramethylene pentaurea was prepared as described by Dixon (2); this worker thought the product to have a 6-membered ring structure, but Zigeuner (10) subsequently repeated the work and concluded that the compound was a methylene urea consisting on average of five urea residues linked by methylene groups. Analyses of our product were in reasonable agreement with the calculated values (Found — nitrogen 40.2%, formaldehyde equivalent 35.3%; calculated — nitrogen 40.2%, formaldehyde equivalent 34.5%).

Methylene ether compounds: A further product was prepared by reaction under alkaline conditions as described by Goldschmidt (3), who considered the product to consist of dimethylol urea; Zigeuner (9), however, subsequently showed the material to be a mixture of two methylene ethers. Recrystallisation of the crude product yielded a substance containing 25.3% nitrogen, and having a formaldehyde equivalent of 55%; one of the two methylene ethers identified by Zigeuner was assigned the formula $HOCH_2.NH.CO.NH.CH_2.O.CH_2.NH.CO.NH.CH_2OH$, the calculated analysis of which is 25.1% nitrogen with a formaldehyde equivalent of 54.0%,

Of the compounds referred to above monomethylol urea, dimethylol urea and methylene diurea can be obtained in relatively pure state. As the chain-length increases in the methylene urea series, however, it becomes increasingly difficult to detect admixture with other members of the series, and it seems unlikely that complete separation will be obtained.

Decomposition of some urea-formaldehyde compounds in soil

Mineralization of the nitrogen of the compounds referred to in the previous section was studied under controlled conditions in the laboratory. Except in a somewhat infertile soil the methylol ureas were found to decompose very rapidly, the monomethylol compound being slightly faster than dimethylol urea; neither of these compounds would have any value as a slow-acting fertilizer. Methylene diurea also decomposed fairly rapidly in the soil, though not as fast initially as the methylol ureas. Dimethylene triurea proved to be less rapidly decomposed in the soil than methylene diurea, and the nitrogen of tetramethylene pentaurea was found to be mineralized relatively slowly. From the results for these three methylene ureas it may be concluded that the rate of release of nitrogen in the soil decreases with increasing chain-length. However, the contrast in rates of decomposition of the tri- and pentaurea compounds is so great that the isolation and testing of the intermediate compound trimethylene tetraurea is much to be desired.

The methylene ether compound appeared from laboratory trials to possess the valuable property of releasing nitrogen over a relatively long period, though its low initial rate of decomposition suggests that admixture with some more readily available source of nitrogen would be necessary if such compounds were to be of practical value as fertilizers. As in previous trials, hoof and horn was shown to decompose relatively quickly in the soil, a high proportion of the available nitrogen being released within three weeks.

The rates of mineralization of the various urea-formaldehyde compounds in a garden soil having an initial *p*H value of 6.1 are shown in Table I. A further set of data for the same soil after treatment with 0.5% of calcium carbonate is shown in Table II.

TABLE I

Percentage mineralization of the nitrogen of some urea-formaldehyde compounds in soil having an initial *p*H of 6.1

Compound	Period of incubation in weeks						
	1	2	3	4	12	16	26
Monomethylol urea	86	83	86	85	96	85	89
Dimethylol urea	78	78	83	75	71	69	66
Methylene diurea	57	85	91	91	97	88	88
Dimethylene triurea	15	75	79	81	93	96	89
Tetramethylene pentaurea ..	—	2	3	3	12	16	20
Crude dimethylene ether ..	27	61	63	69	90	87	91
Hoof and horn..	30	60	65	67	79	80	74

TABLE II

Percentage mineralization of the nitrogen of some urea-formaldehyde compounds in a limed soil

Compound	Period of incubation in weeks						
	1	2	3	4	12	16	26
Monomethylol urea	85	83	87	92	90	86	90
Dimethylol urea	75	78	82	91	86	88	90
Methylene diurea	58	92	90	90	90	84	89
Dimethylene triurea	9	53	81	85	82	82	85
Tetramethylene pentaurea ..	1	3	3	5	4	6	10
Crude dimethylene ether ..	4	23	17	21	74	78	65
Hoof and horn	30	61	71	70	79	76	74

Growth of tomato plants in potting mixtures containing urea-formaldehyde compounds

The urea-formaldehyde compounds referred to in the previous sections were not available in purified form in quantities sufficient for experiments on plant growth on any appreciable scale, nor were some of the compounds considered likely, as judged from laboratory experiments, to merit such investigation. Products representing some of the most interesting types of compound in partially purified form were, however, prepared on a larger scale. Thus in the results which follow sample UFT. 1 consisted of a crude preparation of methylene diurea, prepared by reaction of formaldehyde and a very large excess of urea under acid conditions; the precipitated solid was washed with water to remove free urea but not recrystallised. UFT. 2 represents the methylene ether type of product, precipitated from alkaline solution containing urea and formaldehyde on standing at room temperature for three weeks. The solid product was filtered off, washed free from excess formaldehyde and air-dried. Samples UFT. 3-5 represent methylene ureas prepared by reaction of formaldehyde and urea at *p*H 9 to form methylol compounds, the resulting solution being poured into solutions of urea and acidified to give a *p*H value of 3.5. After reaction at room temperature for 24 hours the precipitates were filtered, washed with alcohol to remove free urea, and air-dried. The conditions of preparation of samples UFT. 3-5 differed only in the concentrations of urea solution in the acid stage of the reaction, these being 250, 500 and 1000 g. urea per litre for UFT. 3, UFT. 4 and UFT. 5 respectively; the higher concentrations of urea may be expected to favour the formation of shorter chain-lengths.

These five samples of urea-formaldehyde, together with hoof and horn as an accepted organic nitrogenous fertilizer for comparison, were included in an observational trial, using tomato plants grown in 10-inch pots. It must be emphasized that in these trials the tomato plants were used simply as indicators of the relative rates of release of inorganic nitrogen; it it is no way implied that the use of heavy applications of slow-acting nitrogenous fertilizers in the compost without subsequent top dressings is necessarily to be considered the best way of using such materials for the growth of tomato plants in pots. For this trial potting mixtures were made up as for J.I.P.3, except that the amount of chalk applied was doubled and the source and concentration of nitrogen were varied. In two of the treatments (hoof and horn and UFT.4) nitrogen was included in the potting mixture at J.I.P.3 level, and all additional nitrogen applied in top dressings of compound fertilizers. The amount of nitrogen applied in the potting soil in these two treatments was 2.53 g. per 10-inch pot, and it was planned to give ten top dressings containing an additional 5.61 g. of nitrogen per pot in all. All five urea-formaldehyde compounds and hoof and horn were also supplied in the potting mixture at the rate of 8.14 g. per pot, that is, with nitrogen equivalent to the combined top dressings and the nitrogen included in the

potting mixture; in these six treatments the top dressings supplied phosphate and potash as before, but no nitrogen whatsoever was given other than that in the potting mixture prior to planting. In the remaining treatment the only nitrogen present was that contained in the soil-peat potting mixture.

Plants of the variety Moneymaker were potted in soil receiving the various treatments on May 24th, approximately seven weeks after sowing. Within a week it was apparent that little or no nitrogen was becoming available from sample UFT.3, and that UFT.4 also was relatively slow-acting; in contrast the colour of the foliage of plants receiving heavy dressings of UFT.1 and of hoof and horn was excessively dark. Urea-formaldehyde sample UFT.2 subsequently appeared to be too slowly available in the soil to maintain good growth and colour. An outbreak of *Botrytis* occurred in July, and proved difficult to control. The first fruit was picked in mid-July, and the experiment was terminated at the end of September.

TABLE III

Height of tomato plants eight weeks after transferring to pots containing compost with various sources of nitrogen added

Plant No.	TREATMENT								
	UFT. 1	UFT. 2	UFT. 3	UFT. 4	UFT. 5	Hoof	Top-dressed		No nitrogen
							UFT. 4	Hoof	
	cm.	*cm.*	*cm.*	*cm.*	*cm.*	*cm.*	*cm.*	*cm.*	*cm.*
1	128	104	86	121	—	136	117	132	89
2	135	105	79	105	150	138	112	126	86
3	135	111	85	129	153	139	111	138	74
4	146	105	91	110	158	150	116	157	83
5	131	107	80	120	144	142	101	125	94
6	132	105	82	112	130	137	112	126	92
7	140	112	84	112	157	140	113	149	92
8	133	107	94	137	146	136	118	152	93
Average	135	107	85	118	148	140	113	136	88

Note: In the first six treatments all nitrogen was applied to the compost before potting. In the remaining two nitrogen treatments the nitrogen source was added to the potting mixture at J.I.P.3 level and subsequently top-dressed with a mixed fertilizer.

The heights of the plants, measured on July 23rd, are recorded in Table III. At this date plants grown in potting mixtures containing UFT.5, hoof and horn and UFT.1, all the nitrogen being included at the time of potting, and hoof and horn with subsequent top dressings gave the maximum growth; plants receiving UFT.3 were no better than those receiving no nitrogenous fertilizer at all. The measurements of height in Table III were subsequently found to be closely related to the total crop yields, particularly if the two treatments in which nitrogenous top dressings were given are excluded.

The total weights of fruit picked per plant are shown in Table IV.

TABLE IV

Yield of fruit from tomato plants grown in pots, using urea-formaldehyde compounds and hoof and horn as sources of nitrogen

Plant No.	TREATMENT								
	UFT. 1	UFT. 2	UFT. 3	UFT. 4	UFT. 5	Hoof	Top-dressed		No nitrogen
							UFT. 4	Hoof	
	g.	*g.*	*g.*	*g.*	*g.*	*g.*	*g.*	*g.*	*g.*
1	1183	492	209	969	2047	1163	1422	1300	463
2	1116	936	584	1051	2197	1462	1586	1468	508
3	1009	838	552	1033	1763	1010	1573	1321	389
4	839	776	654	858	1553	1076	1235	1633	—
5	1089	963	291	819	2069	1252	1369	1617	421
6	—	—	233	857	1865	—	1176	2046	632
7	1295	—	430	924	2027	1356	1080	1873	409
8	—	535	449	582	1795	1178	1537	1751	231
Mean	1088	757	425	887	1845	1214	1372	1626	436

Note: In the first six treatments all nitrogen was applied to the compost before potting. In the remaining two nitrogen treatments the nitrogen source was added to the potting mixture at J.I.P.3 level and subsequently top-dressed with a mixed fertilizer.

The most striking feature of these results is that the yield from plants receiving UFT.5, all the nitrogen supplied as fertilizer being incorporated prior to planting, exceeded that from the conventional use of hoof and horn in the potting mixture with subsequent top dressings. It must be noted, however, that in fact only nine of the ten top dressings allowed for when setting up the experiment were applied before the plants were discarded; plants receiving nitrogen in top dressings thus had 8% less fertilizer nitrogen than plants in the remaining treatments. It is also likely that higher levels of fertilizer would have been desirable throughout; even the maximum yields recorded were not particularly high, though the need to stop all plants at a height of 6ft. and the losses from *Botrytis* doubtless influenced the results.

It is of interest to compare the results of the pot experiments, as shown in Tables III and IV, with the rates of mineralization of the nitrogen of the same compounds in the laboratory. The results of an experiment in which the five urea-formaldehyde compounds and hoof and horn were mixed with batches of the same potting mixture as used in the glasshouse trials are shown in Table V, the level of application being 300 p.p.m. nitrogen expressed on the basis of oven-dry soil.

TABLE V

Percentage mineralization of nitrogen in laboratory tests on urea-formaldehyde products as used in the glasshouse trials

Product	Period of incubation in weeks				
	1	2	3	4	8
UFT. 1	86	92	88	96	93
UFT. 2	2	6	9	16	27
UFT. 3	2	2	5	10	7
UFT. 4	—	3	8	9	14
UFT. 5	24	44	42	59	67
Hoof and horn	34	44	58	64	66

Sample UFT.5 and hoof and horn, the first and second best fertilizers as judged by crop yields and height of plants in the glasshouse trials, were both relatively rapidly decomposed in the soil. UFT.1 (crude methylene diurea) made the plants excessively dark green in the early stages of growth but lacked the sustained effect of UFT. 5; this result may be foreseen from the data for mineralization of nitrogen in the laboratory tests, but nevertheless the plants made quite good growth, probably associated with the very high availability of the nitrogen present. Of the remaining urea-formaldehyde preparations UFT.4 and UFT.2 both proved disappointing in the glasshouse trials and relatively slowly mineralized in the soil; the performance of UFT.2 in the glasshouse pot experiment was indeed below expectation. Sample UFT.3 proved to be quite valueless in the glasshouse trials, a result in accordance with the very low percentage mineralization of nitrogen in the laboratory tests. There is thus a fair measure of agreement between the results of the glasshouse and laboratory tests.

Summary and conclusions

1. Some compounds of urea and formaldehyde have been isolated in relatively pure state, including monomethylol and dimethylol ureas, methylene diurea, dimethylene triurea and tetramethylene pentaurea.

2. Measurements of the rates of mineralization of nitrogen in soils treated with these urea-formaldehyde compounds indicate that the methylol ureas would be too rapidly available to serve as slow-acting fertilizers.

3. Of the methylene ureas, methylene diurea decomposed rapidly in the soil, but compounds of greater chain-lengths proved to be increasingly resistant to breakdown in the soil.

4. The very low "availability" of tetramethylene pentaurea is of interest in that it provides a likely explanation of the low availability of many of the urea-formaldehyde materials previously examined. Thus products having an average chain-length of five or more urea residues may be expected in the mixed products of reaction under acid conditions.

5. Efforts to prepare trimethylene tetraurea will be continued in view of the marked difference in ease of decomposition between the higher and lower members of the methylene urea series.

6. The purified compounds were isolated in quantities too small for glasshouse trials, but less pure preparations representing the different types of compound were used as sources of nitrogen for the growth of tomato plants.

7. Of the five urea-formaldehyde compounds tested as nitrogenous fertilizers for tomato plants, one proved to be too rapidly and three too slowly available for plant growth. The remaining sample, of the methylene-urea type, showed promise as a slow-acting fertilizer.

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5. BORON IN THE NUTRITION OF TOMATO PLANTS

by

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Following an investigation (4) of the growth and fruiting of tomato plants in sand culture at various concentrations of boron, further studies were undertaken with plants grown in soil. In particular, the distribution of boron in relation to leaf position on the plant, seasonal trends in boron content of the leaves, and the effects of added boron on plants grown in a glass-house border were studied.

As previously stated (4), laminae appeared to be the most suitable material for studies of boron uptake, and, except where otherwise indicated, were used for all the analyses now described. Boron in soils and plant materials was determined by the method of Dible, Truog and Berger (2).

The distribution of boron in relation to leaf position on the plant

In order to obtain information on the relationship between boron content of the leaf and its position on the plant, two batches of pot-grown tomato plants of variety Potentate were obtained. The first batch consisted of 12 plants selected for uniformity in May, 1955, from a large group sown in December, 1954. The tops of all twelve plants, consisting of a small cluster of young leaves not separated from each other by any appreciable length of stem, were cut off and bulked together, this sample subsequently being referred to as "tops." The highest remaining leaf was removed from each plant, bulked, and designated as "first leaf," this procedure being repeated at successively lower levels down the plant until the sixteenth leaf was reached; any remaining leaves were omitted, these tending to be contaminated with soil. The petioles were then separated from the laminae in all samples other than the "tops" and first leaves. After determination of percentage dry matter, the laminae were analysed for boron; the opportunity was also taken to study the distribution of nitrogen, phosphorus and potassium in the same samples. The results for boron, nitrogen, phosphorus and potassium are given in Table I; analytical values for phosphorus and potassium have been expressed as the elements themselves rather than as P_2O_5 or K_2O. In considering the data it should be noted that samples designated as "tops" and first leaf are not directly comparable with the remainder, since both laminae and petioles were present; the trends in distribution of the various elements can thus only be studied from the second leaf downwards.

The results show an increasing boron content in the leaves from top to bottom of the plants, with similar trends in potassium and total ash content. In contrast, the percentage dry matter, and to a lesser extent the nitrogen content, decreased from top to bottom.

A further batch of tomato plants, sown in June, was sampled in the same way during October. The results show very similar trends to those already reported, although the range of boron values from second to lowest leaf was smaller.

Seasonal trends in boron content

Duplicate samples of tomato leaves were taken from house D1 (variety: Potentate), D2 (variety: E.S.5) and B2 (variety: E.S.5) on nine occasions from May to September (1955); each sample consisted of 8, 12 or 16 leaves, depending on their size at the time of sampling. Only one leaf was taken from any one plant, the fifth leaf (determined as in the preceding section) being used throughout.

TABLE I

Analyses of leaves from pot-grown tomato plants

Sample	Nitrogen	Phosphorus	Potassium	Boron
	%	%	%	*p.p.m.*
Tops ..	4.70	0.70	3.20	27
1st Leaf ..	3.88	0.57	3.39	35
2nd „ ..	4.01	0.50	2.48	39
3rd „ ..	3.69	0.47	2.49	44
4th „ ..	3.33	0.45	2.43	57
5th „ ..	3.02	0.43	2.66	71
6th „ ..	3.02	0.44	2.76	84
7th „ ..	3.19	0.46	3.12	87
8th „ ..	3.15	0.47	3.68	91
9th „ ..	3.37	0.49	3.89	94
10th „ ..	3.33	0.47	4.19	104
11th „ ..	3.33	0.44	4.24	104
12th „ ..	3.28	0.40	4.88	109
13th „ ..	3.28	0.42	5.35	108
14th „ ..	3.04	0.42	5.40	109
15th „ ..	3.06	0.43	5.59	110
16th „ ..	2.83	0.44	5.91	113

Note: The values given are the amounts in dried material. The first two samples contain both laminae and petioles; from the second leaf downwards the samples consist of laminae only.

In the year that these samples were collected (1955), houses D1 and D2 were being used for spacing trials; the samples taken were entirely from plots planted at a normal density (16,000 plants per acre). The recorded crops in these two houses were exceptionally heavy. In the same year Block B was being used for a uniformity trial, and received 20 tons/acre of stable manure but no other base or top dressings. The crop was markedly lower than in D block, and the plants were very starved and made poor growth. Soil samples were taken from houses D2 and B2 for determination of water-soluble boron. One set of data, for leaves from house D2 (variety: E.S.5), is presented in Table II; data for nitrogen, phosphorus and potassium have again been included. The results show a rising content of boron in the laminae (5th leaf) throughout the season; similar trends in boron content were noted in the other two houses sampled.

TABLE II

Seasonal variation in the content of nutrients in the laminae.

Date	Nitrogen	Phosphorus	Potassium	Boron
	%	%	%	*p.p.m.*
10th May	4.22	0.28	3.16	40
24th May	3.89	0.26	2.86	44
7th June	4.40	0.29	3.23	50
21st June	4.88	0.29	3.18	56
5th July	4.53	0.28	2.61	50
26th July	4.71	0.27	2.57	66
9th August ..	4.79	0.32	2.61	63
23rd August ..	5.33	0.31	2.51	77
6th September ..	5.49	0.30	2.79	77

Note: The results given are for the fifth expanded leaf on plants of the variety E.S.5., and show the amounts of the element indicated in the dried material.

An interesting feature of these investigations is the far higher boron content of plants grown in B block as compared with those from D1 and D2; thus the mean values for boron content of the laminae throughout the season were 133 p.p.m. for house B2 as compared with 54 and 58 p.p.m. for D1 and D2 respectively. This result is at first sight even more surprising in view of the higher content of water-soluble boron in the soil of D as compared with B block (Table III).

TABLE III

Water-soluble boron in soil samples from houses B2 and D2

Date of sampling	House B2	House D2
10th May	—	0.93
24th May	0.61	0.97
7th June	0.70	0.97
23rd June	0.69	1.03
5th July	0.70	0.98
28th July	0.72	1.00
9th August ..	0.65	0.98
23rd August ..	0.69	1.02
6th September ..	0.56	1.03

Note: The results are expressed as p.p.m. boron on the basis of air-dry soil.

The far higher concentration of the main nutrients in houses D1 and D2 is probably the primary factor responsible for the lower content of boron in the plants; vigorous growth and the consequent high boron requirement might be expected to lower the concentration of this element in the tissues. The starvation levels of major plant nutrients in house B2 are well reflected in the crop recorded, and the slow rate of growth in this house may easily have led to accumulation of boron in the tissues.

The reason for the higher boron content of soil in D as compared with B block is uncertain, 1955 being only the second year of glasshouse cultivation on the site and no boron compounds having been applied intentionally. The base and top dressings used in D block might be expected to contain some boron, but unless the fertilizers used carried relatively large amounts of boron as impurities this alone would hardly accoun for the whole difference. Alternatively, the higher concentration of soluble salts may possibly have increased the proportion of the total boron in the soil present in water-soluble form.

TABLE IV

Boron content of young side-shoots removed in pruning treatments

Date of sampling	Series A	Series B
	p.p.m.	*p.p.m.*
5th May	28	26
12th May	35	29
19th May	37	32
4th June	39	38
17th June	43	39
1st July	48	49
18th July	—	42
22nd July	37	32

Note: The results are expressed on the basis of oven-dried tissue.

In addition to the data for the boron content of laminae already described, two further sets of material were examined, both consisting of very young, actively growing tissue; both samples consisted of young laterals, taken from two different pruning treatments in house D3. The young shoots were dried and analysed without any attempt at separation into components. The results, given in Table IV, show a relatively low content of boron in the young, actively growing side-shoots; the boron content of the material again tended to rise until early July, though some decrease was apparent subsequently.

The effect of added boron on the growth and fruiting of glasshouse tomato plants

The boron content of the leaves of tomato plants grown in Block D during 1955, though not so low as that of plants exhibiting deficiency symptoms in sand culture during 1954, was definitely below that of plants then considered to have received an adequate supply of boron (0.2 p.p.m. in the nutrient solution). It was therefore considered of interest to make preliminary observations on the effects of added boron on tomato plants grown in glasshouse borders. For this purpose a trial was laid down in house D2, in 1956, in order to study the effects of boron supply on (1) total yields of fruit, (2) fruit quality, (3) uptake of boron by the plants, and (4) levels of water-soluble boron in the soil throughout the season. Four treatments were applied, these being:—

(*a*) Control; no added boron.
(*b*) Spray; 0.1% solution of borax sprayed on the foliage at intervals during the season.
(*c*) Soil treatment; 10 lb. of borax per acre applied before planting (10.2 g. per plot).
(*d*) Soil treatment; 40 lb. of borax per acre (40.6 g. per plot).

The house was divided into four blocks, blocks 1–4 occupying the N.E., S.E., S.W. and N.W. corners of the house respectively. Each treatment occurred once in each block, giving 16 plots in all. Each plot was planted on March 1st with 40 plants of variety Potentate in two double rows; the area of each plot was 97.5 sq. ft. The plots were separated from each other by one double row of guard plants, with additional groups of guard rows at the ends of the house.

The soil treatments supplying boron were applied in solution immediately before planting. Spray treatments were applied seven times during the season, on March 15th and 29th, April 12th, May 4th and 25th, June 28th and July 26th, the total amount of borax applied being approximately 20 g. per plot.

Samples of leaves for analysis were collected on four occasions during the season, two plants being chosen at random from each of the four single rows per plot; the third leaf below the top was taken to represent young growth and the ninth leaf to represent more mature material, both leaves in each case being from the same plants.

Samples of fruit for analysis were taken from each plot on June 21st and August 17th, only good quality fruit being used.

Soil samples were taken with an auger to a depth of 9 inches on March 1st (before applying boron), March 29th (before spraying with borax), July 5th and August 23rd. Except on the last date, corresponding samples from each block were bulked together for analysis.

Results

A slight but definite marginal scorch, typical of boron toxicity (4), was noted on March 19th, affecting all plots treated at the highest rate of application of borax (40 lb. per acre). This effect was probably aggravated by the mode of application of the borax, namely in solution on

the day of planting; the content of borax in the soil with which the roots of the young plants were in contact was probably unduly high. No visible sign of stunting or check in growth resulted, however.

Measurements of the heights of all plants were made on March 27th, but no significant differences were found between treatments; this result is in contrast to the close relationship between height and boron content in sand-culture during 1954 (4) and suggests that the level of boron in the untreated soil was not inadequate.

On April 12th the colour and general appearance of the plants was assessed independently by two observers, from which it was concluded that plants receiving added boron, particularly at the highest level, generally appeared to be healthier and to have a better colour in the tops. The first signs of virus infection were noted at about this time, and may indeed have influenced these observations on the appearance of the plants. A rather severe outbreak of virus developed, and undoubtedly had an adverse effect on the course of the experiment. Symptoms of virus were first noted in plots not treated with borax, but records of the subsequent development of the outbreak soon showed all treatments to be similarly affected.

TABLE V

Yields of fruit in an experiment on the effect of boron, applied as a spray or in the soil, on tomato plants

	Control	Spray	Soil		Mean
			10 lb. boron per acre	40 lb. boron per acre	
	lb.	*lb.*	*lb.*	*lb.*	*lb.*
Block 1 ..	413	342	429	379	391
2 ..	429	421	410	353	403
3 ..	418	382	379	382	390
4 ..	375	401	344	411	383
Mean ..	409	387	391	381	

Note: The yields given are for a plot of 40 plants.

The total yields of fruit for the season are given in pounds per plot (40 plants) in Table V. Differences between treatment means were not significant, and such small variations as were found were probably due to lack of uniformity in the house, and especially to the North-South gradient. In partial explanation of the reduced yields from the treatment supplying 40 lb. per acre of borax it may be noted that plot 11 was somewhat damaged by glass blown out during a severe gale in July, and that plot 8, by virtue of its position adjacent to the pipe duct at the South end of the house, tended to dry out rapidly and proved difficult to re-wet.

Some evidence was found for an improvement in fruit quality in plots treated with boron. Thus when Grade A fruit was expressed as a percentage of the total fruit graded, it was found that the highest level of added boron (40 lb. borax per acre) gave the highest proportion of top quality fruit, differences between this and the remaining three treatments being significant at the 5% level (Table VI).

TABLE VI

First quality fruit picked in an experiment on the effect of boron, applied as a spray or in the soil, on tomato plants.

	Control	Spray	Soil		Mean
			10 lb. boron per acre	40 lb. boron per acre	
	%	%	%	%	%
Block 1 ..	42.5	40.7	42.6	48.7	43.6
2 ..	39.3	41.0	39.7	51.4	42.9
3 ..	48.0	45.7	43.7	48.3	46.4
4 ..	43.4	45.0	45.0	44.3	44.4
Mean ..	43.3	43.1	42.8	48.2	

Note: First quality fruit is that of regular shape and uniform colour and is expressed as a percentage of the total graded crop.

TABLE VII

The boron content of the foliage at four sampling dates in an experiment on the effect of boron, applied as a spray or in the soil, on tomato plants

Date of sampling	Control	Spray	Soil	
			10 lb. boron per acre	40 lb. boron per acre
	p.p.m.	*p.p.m.*	*p.p.m.*	*p.p.m.*
1st May ..	31	33	33	53
24th May	38	46	40	81
5th July ..	53	84	61	80
25th July..	44	47	48	66

Note: The results are for the laminae only, of the third leaf, and are expressed in p.p.m. on the basis of dry matter, each value being the mean for four plots.

The boron content of the leaves at four sampling dates is shown in Table VII, the results shown being for the third leaf below the tops. The results in general show a higher boron content in plants from all three treatments supplying this element, the effect being particularly marked at the highest level of added borax. The somewhat higher values obtained early in July are referred to in the discussion section.

The boron content of the fruit showed little variation, ranging from 16.6 to 18.8 p.p.m. in the dried material as sampled in June, and from 14.9 to 17.0 p.p.m. in August. On both dates of sampling the highest boron content was found in fruit from plots receiving borax at the rate of 40 lb. per acre, but the overall range was too small for the results to have any practical significance.

The results for water-soluble boron in the soil were closely related to the treatments applied; the boron content of plots to which borax was applied before planting decreased as the season progressed, but levels of boron in the soil were maintained in the sprayed plots by repetition of the treatments.

Discussion of results

Under the conditions of this experiment there appears to have been little or no beneficial response to added boron during 1956. It must be stated, however, that a heavy crop and generally good growth had been regarded by us as an essential prerequisite in these trials, and these conditions were not fully achieved. The improved colour of the young plants and apparent delay in the appearance of symptoms of virus infection were only of short duration, and were not reflected in the subsequent growth. The total crop was not increased by the treatments, and the improvement in fruit quality shown in Table VI would certainly need confirmation before it could be regarded as fully established; poor fruit quality was, however, a feature of the lower levels of boron in the sand-culture experiments during 1954, and evidence of improved fruit quality in field-grown tomatoes receiving added boron has already been obtained elsewhere (1).

The results in Table VII (1956) show a rising boron content in the leaves at the first three dates of sampling, with a marked decrease towards the end of July. The results obtained during early July may be anomalously high, as growth of the plants was still suffering from a rather severe check due to virus; if so, there remains little evidence for declining boron levels in the tissue during July. If, however, the apparent decline in boron content of the leaves during July (1956) is accepted, then the results differ from those given in Table II; in the latter series (1955) the boron content tended to increase throughout the whole season. Some support for a declining boron content during July is given by the results for two sets of side-shoots during 1955 (Table IV). It must therefore be concluded that, whereas a rising boron content is apparent until at least July for all cases so far examined, there is no overall agreement in our data for subsequent trends.

The boron content of the foliage, fruit and soil samples, when compared with published data in this field, suggest that at no time during the 1956 trials were the plants suffering from any real deficiency of this element, though the levels may be considered in general to be relatively low. In making such comparisons it should be noted that our boron data are based on analyses of laminae only, and that the petioles have a lower boron content. The amounts of boron present in the foliage from the glasshouse trial of 1956 were below those of plants making the best growth in sand-culture, though higher than that of plants showing deficiency symptoms in the latter trials.

Before proceeding with further experiments on the effects of boron on glasshouse tomatoes, it is now considered essential that the precision of these glasshouse trials should be increased as far as possible; further studies of the macro-nutrients are meanwhile proposed as one aspect of any such improvements, together with the use of improved techniques for the application of nutrients and more rigid control of cultural practices. Furthermore, when studies of the effects of boron are ultimately resumed, it will probably be desirable to include foliar sprays containing boron not only alone but also in combination with sugars and plant growth substances (3).

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6. A CRITICAL RE-EXAMINATION OF THE CONVENTIONAL CONDUCTIVITY (pC) TEST FOR SOLUBLE SALTS IN SOILS

by

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It is well-known that the concentration of soluble salts in the soil influences plant growth and that, in particular, excessively high salt concentrations restrict growth. Measurements of the electrical conductivity of aqueous extracts or suspensions of soils have been used as a means of determining the content of soluble salts since the beginning of the century (5, 12). Subsequent research has shown that a useful measure of the soluble salt content can be obtained by this means (4, 6, 8, 11, 14).

In this country the results of conductivity determinations, measured in mhos, are commonly expressed as *p*C values, the term *p*C being used for the negative logarithm of the specific conductivity of the extracts or suspensions (13). There has been some diversity of opinion on the best water:soil ratio to use in the preparation of extracts for conductivity measurements, but a ratio of 2.5:1 is widely used. Under these conditions the *p*C values generally encountered range between approximately 4.0 and 2.4. Values below 2.6 to 2.8 are generally considered to be unfavourable to glasshouse crops, but the subject of salt tolerance by plants is complicated by many factors (9).

Measurements of the electrical conductivity of suspensions or extracts prepared at some arbitrary water:soil ratio are convenient for rapid routine analysis, and have the advantage of requiring only relatively small quantities of soil; outside the range of obvious plant injury from excessively high concentrations of soluble salts, however, it is now suggested that the results obtained are not always as useful as might be expected. The value of such determinations on soil suspensions prepared by adding arbitrary amounts of water to the soil will, indeed, largely depend on the nature of the soluble salts present. Sparingly soluble salts will not be in solution to any great extent at field moisture content, but during the preparation of the extract will be dissolved either wholly or in part. Old glasshouse soils can be particularly high in calcium sulphate, values of 4000 p.p.m. sulphate or more being not uncommon. In such soils the apparent amount of soluble salts present will depend on the water:soil ratio. Ideally it would be preferable to assess the concentration of soluble salts in the soil moisture encountered by the plant roots, but this is virtually unrealisable in practice. It should be possible, however, so to modify the conditions of the test as to make it less far removed from natural soil conditions.

In this report some preliminary experiments are described in which an attempt has been made to relate *p*C determinations at various water:soil ratios to plant growth in soils containing different levels of fertilizer and of calcium sulphate.

Experimental methods and materials

The potting mixture used in these experiments consisted of five parts of steamed loam to one part of peat. Batches of this mixture were treated with a water-soluble mixed fertilizer at five different levels, namely 0.125, 0.25, 0.5, 0.75 and 1.25%. The fertilizer consisted of equal parts by weight of diammonium hydrogen phosphate and potassium nitrate, giving a mixture containing 17.5%N, 26.9% P_2O_5 and 23.3% K_2O. In order to minimize differences in soil *p*H arising from the various fertilizer levels, pure finely divided calcium carbonate was also added in amounts corresponding to one fifth of the mixed fertilizer per pot. Determinations of *p*H at the end of the experiment showed relatively little variation between treatments, actual values

PLATE 1. Lettuce plants (variety: Cheshunt Early Giant) from each of the 20 treatments. Levels of fertilizer increase from left to right and of calcium sulphate from front to rear.

PLATE 2. Peas (variety: Little Marvel) from each of the 20 treatments. Levels of fertilizer increase from left to right and of calcium sulphate from front to rear.

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ranging from 6.1 to 6.8 with a mean value of 6.4. The five different fertilizer levels were also combined with four levels of calcium sulphate, namely 0, 0.15, 0.75 and 1.5%, thus making twenty treatments in all. All amendments were mixed thoroughly with the soil. The various treatments were replicated four times for lettuce and twice for peas.

Lettuce (variety Cheshunt Early Giant) at the 3 – 4 leaf stage were transplanted into the different mixtures in 6-inch clay pots. At the same time peas (variety Little Marvel) were sown at the rate of five per pot directly into the various mixtures. The treatments were arranged at random along a glasshouse bench, with guard plants at each end. Losses of soluble salts from the pots during growth were kept to a minimum by careful watering.

Conductivity measurements were made with a Mullard Conductivity Bridge on soil suspensions prepared at soil:water ratios of 1:1, 1:2.5 and 1:5. In addition the conductivity of soil saturation pastes, prepared according to Magistad *et al* (10), was measured, together with that of soil solutions prepared by displacement with alcohol. All conductivity measurements were made at 20°C.

Results

Plate I shows one lettuce plant from each of the twenty different treatments, arranged from left to right in order of increasing fertilizer application, and from front to rear in order of increasing calcium sulphate application. It can be seen that increasing fertilizer levels were accompanied by decreased growth; increasing calcium sulphate levels had little discernible effect, however.

These visual observations are supported by measurements of the fresh weight of the plants. Twenty-nine days after the beginning of the experiment the lettuce were cut off at soil level and weighed. Mean weights for each treatment are given in Table I.

TABLE I

Mean fresh weights of lettuce in an experiment in which the concentration of soluble salts in the soil was varied by additions of fertilizer and/or calcium sulphate

Fertilizer added (%)	Calcium sulphate added (%)				Mean
	0.	0.15	0.75	1.5	
	g.	*g.*	*g.*	*g.*	*g.*
0.125	26.4	29.0	37.1	34.7	31.8
0.25	33.5	29.4	29.3	34.1	31.6
0.50	17.5	24.7	26.9	28.8	24.5
0.75	20.7	14.3	21.2	22.2	19.6
1.25	6.4	6.7	5.4	10.4	7.2
Mean	20.9	20.8	24.0	24.6	

Whereas there was a marked reduction in fresh weight with increasing concentrations of fertilizer, increasing levels of calcium sulphate were not accompanied by marked variations in fresh weights. Statistical analysis of these results shows that for the various fertilizer levels a difference between means exceeding 4.9 g. is required for significance at the 5% probability level, whereas differences greater than 4.4 g. are required for significance with the different calcium sulphate levels. There are thus no significant differences in mean fresh weight of lettuce at the various levels of calcium sulphate.

The effect of the various soil treatments on the growth of peas is shown in Plate II. Increasing fertilizer applications above the 0.25% level reduced germination, but the surviving plants subsequently grew well. There was again no discernible effect of increasing the calcium sulphate level.

When the lettuce were harvested the soil from the pots of each treatment was mixed, air-dried and samples taken for conductivity determinations. Tables II and III show the *p*C results obtained using water:soil ratios of 2.5:1 and 5:1 respectively.

TABLE II

*p*C values as determined at a water:soil ratio of 2.5:1 (suspension)

Fertilizer added (%)	Calcium sulphate added (%)			
	0	0.15	0.75	1.5
0.125	3.02	2.84	2.58	2.55
0.25	2.79	2.68	2.53	2.54
0.50	2.66	2.62	2.42	2.40
0.75	2.66	2.56	2.40	2.40
1.25	2.47	2.44	2.28	2.28

TABLE III

*p*C values as determined at a water:soil ratio of 5:1 (suspension)

Fertilizer added (%)	Calcium sulphate added (%)			
	0	0.15	0.75	1.5
0.125	3.27	3.07	2.72	2.62
0.25	3.06	2.93	2.68	2.60
0.50	2.93	2.87	2.59	2.58
0.75	2.90	2.83	2.57	2.51
1.25	2.71	2.68	2.44	2.39

As previously stated, visual observations on the plants, together with the data for fresh weights, indicated that whereas increasing fertilizer applications were accompanied by decreased growth, calcium sulphate had little effect. In contrast, Tables II and III show that at water:soil ratios of 2.5:1 and 5:1 the *p*C values decreased with increasing levels both of fertilizer and of calcium sulphate.

Tables IV, V, VI and VII show the *p*C values of 1:1 water:soil suspensions, the filtrates from 1:1 suspensions, saturation paste extracts and displaced soil solutions respectively.

TABLE IV

*p*C values as determined at a water:soil ratio of 1:1 (suspension)

Fertilizer added (%)	Calcium sulphate added (%)			
	0	0.15	0.75	1.5
0.125	2.86	2.67	2.65	2.60
0.25	2.63	2.52	2.58	2.57
0.50	2.55	2.51	2.38	2.37
0.75	2.49	2.40	2.40	2.34
1.25	2.38	2.36	2.21	2.21

TABLE V

*p*C values as determined at a water:soil ratio of 1:1 (filtered)

Fertilizer added (%)	Calcium sulphate added (%)			
	0	0.15	0.75	1.5
0.125	2.66	2.49	2.42	2.40
0.25	2.42	2.35	2.35	2.35
0.50	2.31	2.29	2.25	2.25
0.75	2.31	2.23	2.16	2.18
1.25	2.26	2.10	1.93	1.96

TABLE VI

*p*C values as determined in saturation paste extracts

Fertilizer added (%)	Calcium sulphate added (%)			
	0	0.15	0.75	1.5
0.125	2.45	2.36	2.36	2.30
0.25	2.23	2.25	2.26	2.25
0.50	2.12	2.14	2.21	2.10
0.75	2.13	2.06	2.02	2.07
1.25	1.98	1.95	1.82	1.84

TABLE VII

*p*C values as determined in displaced soil solutions

Fertilizer added (%)	Calcium sulphate added (%)			
	0	0.15	0.75	1.5
0.125	2.01	2.01	2.04	1.96
0.25	1.87	1.87	1.96	1.93
0.50	1.79	1.84	1.82	1.84
0.75	1.72	1.70	1.79	1.74
1.25	1.67	1.65	1.65	1.65

It will be seen from Tables IV to VII that, as the amount of water added in the *p*C determination is decreased, the effect on the *p*C value of calcium sulphate incorporated in the potting soil decreases, while at the same time increasing fertilizer levels in the soil are still accompanied by a decrease in *p*C value. In the case of the displaced soil solutions, where no water is added during the determination, there is little difference at any one fertilizer level between the *p*C values for the different levels of calcium sulphate (Table VII).

A comparison of Tables IV and V shows that in every case conductivity determinations on the filtrates from suspensions prepared at a water:soil ratio of 1:1 (Table IV) were higher than the corresponding values measured directly in the suspensions (i.e., the *p*C values were lower). A similar but far less marked effect was found at a water:soil ratio of 2.5:1.

In an attempt to avoid complications arising from the presence of differing concentrations of calcium sulphate in the soil samples, these apparently having little or no effect on growth of the plants, further determinations were made in which an excess of pure calcium sulphate was deliberately added to all soil samples during preparation of the suspensions. The results of these further tests are given in Tables VIII, IX and X for water:soil ratios of 1:1, 2.5:1 and 5:1 respectively. Comparison of these values with the corresponding results in Tables IV, II and III shows that, although the range of *p*C values is restricted, the effect on the *p*C values of varying amounts of calcium sulphate in the soils was largely eliminated.

TABLE VIII

*p*C values as determined at a water:soil ratio of 1:1 (suspension) with excess calcium sulphate added when preparing the suspensions

Fertilizer added (%)	Calcium sulphate added (%)			
	0	0.15	0.75	1.5
0.125	2.57	2.53	2.52	2.49
0.25	2.54	2.52	2.55	2.56
0.50	2.41	2.41	2.41	2.42
0.75	2.37	2.29	2.25	2.27
1.25	2.25	2.26	2.20	2.23

TABLE IX

*p*C values as determined at a water:soil ratio of 1:1 (suspension) with excess calcium sulphate added when preparing the suspensions

Fertilizer added (%)	Calcium sulphate added (%)			
	0	0.15	0.75	1.5
0.125	2.56	2.56	2.57	2.56
0.25	2.52	2.51	2.53	2.52
0.50	2.42	2.45	2.41	2.43
0.75	2.36	2.37	2.40	2.42
1.25	2.27	2.28	2.25	2.25

TABLE X

*p*C values as determined at a water:soil ratio of 5:1 (suspension) with excess calcium sulphate added when preparing the suspensions

Fertilizer added (%)	Calcium sulphate added (%)			
	0	0.15	0.75	1.5
0.125	2.61	2.61	2.61	2.60
0.25	2.56	2.57	2.58	2.58
0.50	2.51	2.52	2.51	2.54
0.75	2.47	2.48	2.47	2.50
1.25	2.38	2.39	2.35	2.37

Relation between the pC data and the fresh weights of the lettuce

Correlation coefficients relating the fresh weights of the lettuce to the *p*C data at various water:soil ratios are given in Table XI.

TABLE XI

Correlation between lettuce fresh weights and *p*C values determined by various methods

Method	Correlation coefficient	Significance
Displaced soil solution ..	r=0.883	P=0.001
Saturation paste extract ..	=0.840	=0.001
1:1 water:soil suspension	=0.694	=0.001
2.5:1 „ „ „	=0.483	=0.05
5:1 „ „ „	=0.298	—

It is apparent that, as the amount of water added in the *p*C determination increases, the significance of the relationship between the fresh weights and the soil data decreases. Thus where no water is added, as in the case of the displaced soil solutions, there is a highly significant positive correlation, whereas at a water:soil ratio of 5:1 the correlation coefficient is not significant. However, a plot of the *p*C results at the 5:1 water:soil ratio against the fresh weights of the plants shows that the points tend to fall into two distinct groups, each of which shows the same trend (Figure 1). The upper set of points represents data for soils receiving 0 and 0.15% calcium sulphate at each of the five levels of added fertilizer, while the lower set represents the 0.75 and 1.5% calcium sulphate levels. Calculation of the correlation coefficients for the two groups separately gives values of 0.789 (P=0.01) and 0.895 (P=0.001) for the two lower and two higher levels of calcium sulphate respectively. A similar but not so pronounced tendency for the data to fall into two distinct groups is also to be seen when the *p*C data for the 2.5:1 water:soil ratio are plotted against the fresh weights.

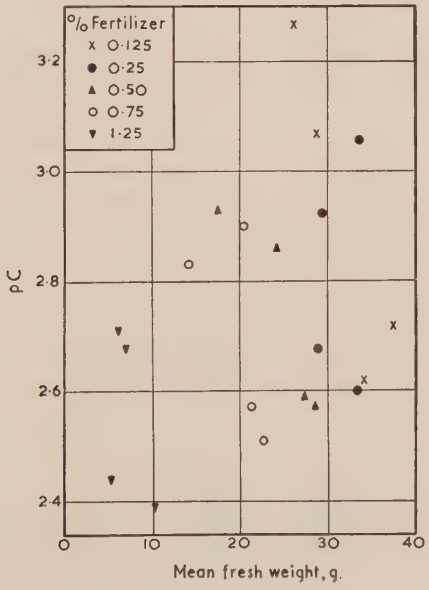

FIGURE 1. Relation between mean fresh weights of lettuce plants and *p*C values as determined at a water:soil ratio of 5:1.

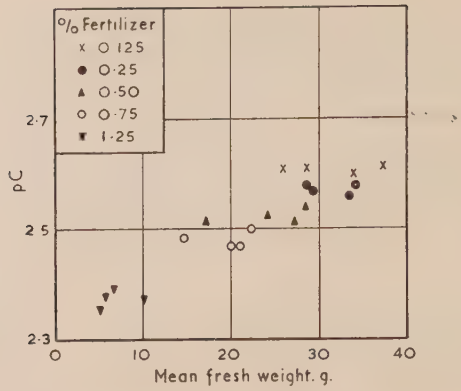

FIGURE 2. Relation between mean fresh weights of lettuce plants and *p*C values as determined at a water:soil ratio of 5:1 in the presence of added calcium sulphate.

Correlation coefficients between fresh weights of lettuce and the conductivity data of Tables VIII — X, in which excess calcium sulphate was added when preparing the soil suspensions, are given in Table XII; for all three ratios of added water to soil from 1:1 to 5:1 the correlation coefficients were highly significant, and thus showed considerable improvement over the data of Table XI. Figure 2 shows a plot of the data at the 5:1 ratio for comparison with Figure 1.

TABLE XII

Correlation between lettuce fresh weights and *p*C values determined at various water:soil ratios in the presence of excess calcium sulphate

Method	Correlation coefficient	Significance
1:1 water:soil ratio ..	r=0.866	P=0.001
2.5:1 „ „ „ ..	=0.927	=0.001
5:1 „ „ „ ..	=0.931	=0.001

Discussion

Butters (2), working with young tomato plants, has shown that additions of calcium sulphate to the soil in amounts giving a *p*C value of 2.7 had little or no effect on growth, whereas similar *p*C values produced by applications of ammonium nitrate caused damage. He also states elsewhere (3) that for maximum yield of tomatoes combined with good quality, *p*C values should be maintained between 3.0 and 3.2. It is emphasised, however, that such recommendations will only hold for soils low in soluble sulphates, and that although low *p*C values resulting from large residues of sulphates are not harmful, there is no means of determining the optimum range of *p*C values in such soils.

In the present investigations addition of soluble fertilizer above the 0.25% level markedly reduced the growth of lettuce, whereas the addition of calcium sulphate had no significant effect. In contrast, increasing applications both of fertilizer and of calcium sulphate reduced the *p*C values as determined at the conventional 2.5:1 water:soil ratio. A situation thus arises in which the conventional conductivity test reflects the presence of increasing levels both of soluble fertilizer and of sparingly soluble calcium sulphate, whereas the plants appear to be sensitive only to high

concentrations of the former. In such cases the conventional determination of the conductivity of aqueous extracts or suspensions, prepared at water:soil ratios of 2.5 or higher, would seem to have little or no diagnostic value.

It is of interest that Grainger (7) found that *p*C values below about 3.0 were likely to cause severe damage to lettuce. In the present experiments, in the absence of added calcium sulphate *p*C values (water:soil ratio 2.5:1) lower than about 2.8 were accompanied by a marked reduction in growth, but no signs of tip-burn or other damage were observed. Moreover, heavy applications of calcium sulphate at the lower fertilizer levels gave *p*C values of about 2.55 without the appearance of obvious deleterious effects of any sort. It may be noted, however, that the present experiments differed somewhat from those of Grainger in that, as previously stated, high salt concentrations were achieved without any appreciable degree of acidity.

A saturated solution of calcium sulphate has a *p*C value of approximately 2.7. In soils containing considerable amounts of calcium sulphate, but low in readily soluble salts such as nitrates, the latter will make only a relatively small contribution to the *p*C of extracts prepared at water:soil ratios of 5:1 or 2.5:1. In such cases the *p*C values will bear little or no relationship to plant growth (Table XI). At lower water:soil ratios, however, there is a highly significant relationship between *p*C and fresh weights; here the soluble salts other than calcium sulphate make a relatively greater contribution to the conductivity of the extract or suspension, and the masking effect of the calcium sulphate is considerably reduced.

Of the methods compared in Table XI, the displaced soil solution gives the best relationship between *p*C values and plant growth, but owing to the time and amount of soil required this method is unsuitable for routine use, at least in its present form. American workers have recommended the use of the saturation paste extract as a general method for appraising soil salinity in relation to plant growth (1). This, too, is somewhat time-consuming and requires some experience if reproducible results are to be obtained.

In contrast to methods involving displaced soil solutions or extracts from saturation pastes, those of our experiments in which calcium sulphate was added to the soil when preparing suspensions for conductivity measurements represent a more empirical approach to the problem, the simplicity of the conventional test at a 2.5:1 water:soil ratio being retained at the expense of some loss of desirability from a fundamental viewpoint. Within the limits of the present experiments this empirical approach was particularly successful; the correlation coefficients given in Table XII for water:soil ratios of 2.5:1 and 5:1 in the presence of added calcium sulphate are the highest obtained in these investigations. Whether or not any such simple modification would be as successful when applied to a range of different glasshouse soils is not yet known.

TABLE XIII

Comparison of conductivity and *p*C values determined by various methods

	Soil Solution	Saturation Extract	Water:soil suspensions		
			1:1 (filtered)	2.5:1	5:1
mhos $\times 10^{-3}$	11.0	5.55	4.47	2.98	2.07
*p*C	1.96	2.26	2.35	2.53	2.68

Arising from the use of displaced soil solutions, saturation extracts or even of low water:soil ratios, it may be noted that the relatively high concentrations of soluble salts encountered under such conditions result in a very restricted range of values when the *p*C notation is adopted. This point is illustrated in Table XIII, where *p*C values and the corresponding conductivity values in mhos $\times 10^{-3}$ are compared for one soil at different water:soil ratios.

It is considered that at low water:soil ratios it would be preferable to express results in conductivity units rather than as *p*C values. The latter tend to give a somewhat misleading impression of the magnitude of differences when salt concentrations in the extract are high.

It is hoped that further work on this subject will be undertaken in the future.

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7. SOME ASPECTS OF THE CASING LAYER IN RELATION TO FRUITING OF THE CULTIVATED MUSHROOM

by

P. B. FLEGG

When mushroom research was restarted following its transfer from the Mushroom Research Station at Yaxley, facilities were not immediately available to allow extension of the work on physical aspects of the casing layer. It was therefore decided to begin work on two hitherto neglected aspects of the casing layer.

(1) Although the hypothesis that fruiting is related to the extremes of nutritional status presented by the compost and the casing layer was put forward many years ago and is still quoted, there is surprisingly little direct evidence that either supports or refutes it. It was decided, therefore, to examine the function of the casing layer from the nutritional aspect.

(2) The addition of salts, usually sodium chloride, to the casing layer has been practised by some growers, and is reputed to improve the quality of the mushrooms and to prevent or control certain diseases. Stoller (6) and Edwards (2) carried out experiments involving the addition of a variety of substances to the casing layer, with inconclusive results. The position has never been systematically examined, however, despite the claims of growers which suggest that this might be a fruitful field of investigation.

The preliminary work consisted of laboratory experiments in which mushrooms were grown in beakers of 1 litre capacity containing compost, these being cased with subsoil to which various substances were added at several levels.

Experimental procedure

The main experiments were carried out in 8-inch cement plant pots lined with thin sheet plastic or painted with a bituminous paint in order to reduce moisture losses. Trials showed little or no difference in yield between pots lined with plastic and those coated with bituminous paint. Because of this, and the greater convenience when filling the pots with compost, painting has been adopted as the most satisfactory pot lining. The compost in these experiments was made from wheat straw and M.R.A. activators, composted for four weeks and turned at weekly intervals. About 3 — 4 lb. of compost were placed in each pot and firmly packed. The pots were placed on shelves in the growing house, peak heated with live steam and spawned with manure spawn, one piece per pot. In order to facilitate the analytical work on the casing layer subsoil dug on the site was used in preference to peat mixtures. Immediately before casing the top layer of compost which had dried out was removed. This allowed the mycelium to move into the soil very soon after casing, and avoided excessive variations in the time taken for the first appearance of pinheads due to uneven moisture conditions at the compost-soil junction. The pots were cased with moist soil about three weeks after spawning, in quantities equivalent to 1 Kg. per pot calculated on an oven-dry basis. To each pot was added 20 g. calcium carbonate which was mixed into the soil at casing. Apart from the experimental treatments all pots were treated as far as possible according to good growing practice. However, after trashing, no extra soil was put on the pots as this would have upset many of the treatments and interpretation of the subsequent analytical work.

Methods of analysis

Measurements of *p*H and *p*C were made on suspensions of soil or milled compost prepared at a water/solid ratio of 2.5:1.

Water-soluble salts in the soil were extracted by shaking 50 g. of ground (1 mm.) air-dry soil in 250 ml. distilled water for one hour in an end-over-end shaker. After shaking, heavier particles were allowed to settle for a few minutes and the supernatant liquid then filtered through a filter candle under suction. An aliquot of the filtrate, with the addition of a few ml. of hydrogen peroxide, was then evaporated to dryness, dried, cooled and weighed. Determinations of water-soluble salts in the dried milled compost were made in the same way, except with regard to the ratio of water to compost. Several water/compost ratios were tried ranging from 25:1 to 250:1; little difference in soluble salt content was found at the various ratios, however, and a ratio of 50:1 was finally adopted. It was found necessary to add considerably more hydrogen peroxide to oxidise organic matter in the filtrates from composts than from soil.

Addition of organic nutrients to the soil

The first experiment in this series, P.3, concerned the addition of calcium oxalate as a source of carbon to the casing soil. Four levels of calcium oxalate were tested, namely 0, 1.06, 10.6 and 106 g. per pot, corresponding to 0, 0.02, 0.2 and 2.0% of carbon in the soil. The treatments were applied one day after casing the pots, each being replicated five times. Preliminary experiments in beakers had suggested that the addition of sugars to the soil might result in undesirable side effects such as invasion by competitive or injurious organisms and micro-biological action causing the soil to become impermeable to water. Calcium oxalate, which is reported to be utilised by the mushroom mycelium (1, 8), was chosen as a carbon source in order to avoid, or at least minimise, these side effects, and in this the experiment appeared to be successful. The experimental results are shown in Table I; in this and all subsequent tables differences from control means significant at the 5% and 1% levels are indicated by one and two asterisks respectively.

TABLE I

Experiment P.3

Effect on fruiting of calcium oxalate added to the casing soil

	Weight of calcium oxalate (*g. per pot*)				S. E. of means
	0	1.06	10.6	106	
Days, casing to 1st pinheads	16.8	18.2	20.0*	23.8**	±0.77
Days, casing to 1st picking	23.4	23.8	26.8	33.4	
Mean yields, g. per pot at 2 weeks	81.6	80.5	90.0	54.8	
,, ,, ,, ,, 6 ,, ...	115.2	121.2	132.6	85.4	
,, ,, ,, ,, 10 ,, ...	144.2	144.4	165.4	117.0	±18.2
Mean numbers per pot at 2 weeks	7.0	8.2	7.2	2.4	
,, ,, ,, ,, 6 ,, ...	12.0	12.4	12.2	4.2	
,, ,, ,, ,, 10 ,, ...	15.8	15.4	16.6	6.6**	±2.17
Mean weight (g.) per mushroom at 10 weeks	9.2	9.4	10.0	17.7	

It was thought that the disadvantages of adding sugars to the soil might be overcome by adding simultaneously a source of nitrogen and phosphorus; in this way much of the added sugar and inorganic nitrogen would, at least temporarily, be transformed into other organic combinations by the soil organisms (7). Two levels of nitrogen, namely 0.25 and 0.5 g. per pot supplied in the form of urea, were chosen, together with sucrose, to give C:N ratios of 20:1, 10:1 and 5:1. Phosphorus, at the rate of one-fifth of the weight of nitrogen, was added as di-sodium phosphate. This gave a set of six treatments. There were two further treatments, in one of which 50 g. of milled dried compost were added to the casing and in the other 0.5 g. nitrogen was added to each pot as casein;

these, together with the control, made a total of nine treatments. The experiment, P.8, was designed as a 9 x 9 Latin square making use of 81 pots, each treatment being replicated nine times. Details of the treatments and the results are shown in Table II. The treatments were applied in solution at the rate of 150 ml. per pot, and the controls received the same quantity of water. In this experiment it was intended to investigate the effect of nutrients added in a relatively simple form at several levels, together with sources of nutrients such as milled compost which may be considered to contain all or most of the requirements of the mushroom.

TABLE II

Experiment P.8

Effect on fruiting of organic nutrients added to the casing soil

	Additions per pot (1 Kg. soil)†									S. E. of means
	0.5 g. N and 0.1g. P			0.25g. N and 0.05g. P			Dried Compost 50g.	Casein 0.5g. N	No Addition	
	10g. C	5g. C	2.5g. C	5g. C	2.5g. C	1.25g. C				
Days, casing to 1st pinheads	28.8**	26.7**	25.6**	27.2**	25.2*	24.7*	25.0*	26.3**	22.3	±0.78
Mean yields, g. per pot at 8 weeks ..	259.2	252.4	255.5	270.0	265.2	261.9	256.9	232.8	267.0	±10.9
Mean numbers per pot at 8 weeks ..	23.1	21.7	29.8	26.2	29.1	27.9	24.0	23.1	26.4	±1.73
Mean weight (g.) per mushroom at 8 weeks	11.2	11.6	8.5	10.3	9.1	9.4	10.6	10.1	10.1	

† Nitrogen (N) added as urea. Phosphorus (P) added as disodium phosphate. Carbon (C) added as sucrose.

Some work on the addition of various proportions of compost to the casing soil has already been reported previously (4) and another experiment, P.4, was designed as an extension of this. For this experiment milled dried compost was mixed with the casing soil at four concentrations. The compost was taken from the stack at filling, air-dried and milled to pass through a 2 mm. sieve. To the casing soil on each pot was added 0, 50, 100 or 200 g. of milled compost which was stirred in with a spatula. Milled compost and soil are not very easy to mix, particularly when the proportion of compost is high, because of considerable differences in particle size and density. As the compost was added in an air dry state considerable care was needed in the early stages to ensure that it was wetted thoroughly during watering. In the later stages mycelium permeating the milled compost tended to make areas of the surface waterproof, and from time to time it was necessary to disturb the casing layer slightly to allow water to penetrate.

So encouraging were the results from this experiment, shown in Table III, that a large-scale trial, Experiment B.3, was set up making use of plots each about 18 square feet in area. There were four shelf beds, each shelf serving as a block in which there were eight plots separated by partitions. The eight treatments included a control, in which there was no addition to the soil apart from a standard amount of ground limestone (2% by volume), two treatments in which milled dried compost was applied at 2 and 4 oz. per square foot respectively, and five further treatments in which various types of hormone compounds were added to soil and compost. The latter, which produced no significant results, will not be described in this report. As in the pot experiments, the milled compost was applied dry and raked into the soil, but in this experiment the difficulties in watering were much less. The cropping details of the control beds and those to which milled dried compost was added are shown in Table IV.

TABLE III

Experiment P.4

Effect on fruiting of milled dried compost added to the casing soil

	Milled dried compost (*g. per pot*)				S. E. of means
	0	50	100	200	
Days, casing to 1st pinheads	18.8	21.2	24.4**	27.2**	±0.86
Days, casing to 1st picking	24.4	28.2	30.6	36.4	
Mean yields g. per pot at 2 weeks	84.0	97.0	82.4	90.8	
„ „ „ „ 6 „	109.6	152.4	127.4	140.8	
„ „ „ „ 10 „	124.6	194.0**	143.4	163.4*	±11.9
Mean numbers per pot at 2 weeks	8.4	9.0	6.0	7.4	
„ „ „ „ 6 „	12.2	15.6	10.6	10.8	
„ „ „ „ 10 „	14.6	21.0**	13.8	12.4	±1.60
Mean weight (g.) per mushroom at 10 weeks	8.6	9.2	10.4	13.1	

TABLE IV

Experiment B.3

Effect on fruiting of milled dried compost added to casing soil on shelf beds

	Weight of milled dried compost (*oz./sq. ft.*)			S. E. of means
	0	2	4	
Days, casing to 1st pinheads	17.50	18.25	20.25**	±0.68
Days, casing to 1st picking	21.75	20.50	22.25	
Mean yields, lb. sq. ft. at 4 weeks	0.69	0.79	0.76	±0.04
„ „ „ 8 „	1.14	1.44**	1.42**	±0.067
„ „ „ 10 „	1.32	1.59*	1.58*	±0.081
Mean numbers per sq. ft. at 8 weeks.. ..	50.9	50.2	43.7	±4.2
„ „ „ „ 10 „ ..	58.1	55.0	50.5	±4.2
Mean weight (oz) per mushroom at 10 weeks	0.36	0.46	0.50	

In experiments in which it is intended to raise the level of nutrients in the casing layer to that in the compost there exists the difficulty of assessing the relative amounts of available nutrients. There is no evidence to show the equivalent nutritional value to the mushroom of compost in terms of sugars and similar organic food sources. Using milled dried compost as the source of food in the casing layers, however, it is calculated that the highest level of dried compost in experiment P.4, 200 g. per Kg. soil, is comparable on a volume basis with the compost in the bed, both compost and casing layer containing the equivalent of about 2.5 — 3.5 g. dry compost per cubic inch.

Discussion of results

The main cropping characteristics which have been examined are the time taken from the application of the casing soil and treatments to the first appearance of pinheads, and the numbers and weight of mushrooms produced. Although the time from casing to first picking is also given, it is fairly closely related to the appearance of pinheads and is subject to variations

due to the stage of development of the mushrooms when picked. Even observing the first appearance of pinheads is not straightforward, some pinheads forming in positions such that they are readily observed when only a few millimetres in diameter, whereas others are not visible until over a centimetre across. Less personal judgment is involved, however, in recording the first appearance of pinheads than when deciding whether to pick a mushroom; the former characteristic is thus preferred as giving an assessment of the beginning of fruiting.

In general the effect of additions of organic nutrients to the soil was to delay fruiting. Thus the high levels of oxalate in experiment P.3, the high levels of dried compost in experiment P.4, and all additions of organic nutrients in experiment P.8 significantly delayed the formation of the first pinheads. In the bed experiment B.3, the high level of milled dried compost also delayed the appearance of pinheads by a significant period of 2.75 days. This adverse effect on fruiting was, however, not maintained. In experiment P.3, as shown in Table I, the differences in weight of mushrooms after ten weeks picking were not significant, but the highest level of oxalate significantly reduced the number of mushrooms. In no other case was the number of pinheads lower than on the control pots and there is evidence, which will be discussed later, that the main effect of the high levels of added calcium oxalate was physical rather than nutritional. Experiment P.8 also produced no significant differences, either in weight or numbers, between the untreated soil and those to which additions had been made.

Milled dried compost added to the soil at the rate of 50 g. per pot in experiment P.8 had no significant effect on cropping, but in experiments P.4 and B.3 some of the differences were particularly large. In experiment P.4 a highly significant increase in weight and numbers per pot of about 50% was obtained by addition of 50 g. dried compost per pot; even as much as 200 g. dried compost per pot resulted in a significantly increased yield although the increased yield from the pots to which 100 g. was added was not significant. Not only was the total weight of mushrooms increased but the individual mushrooms produced were heavier. Apart from the bearing that this result may have on our understanding of the functions of the casing soil, it is of considerable interest from a practical standpoint. On mushrooms beds, each about 18 sq. ft. in area, the addition of 2 and 4 oz. of milled dried compost per square foot gave a significant increase in yield of nearly 25% after eight weeks' picking and over 20% after ten weeks, again with a tendency for heavier mushrooms.

It is difficult at this stage to determine the cause of this considerable increase in yield. The addition of quantities of milled dried compost may have altered the physical characteristics of the casing layer, these already being known to affect yield (3). Certain levels of unmilled compost added to the soil have previously been shown to increase yield (4). In both this and the present series of experiments there is evidence of an optimum level of addition, whereas experiments on the effect of increasing porosity previously carried out with various peat mixtures (3) showed no optimum over a range of porosities from 50% to 90%. It was noticeable during the recent experiments that the milled compost was affected by the mushroom mycelium, the typical pink-brown colour of compost being colonised by the mycelium being readily observed in the casing. If the increase in yield is due to the addition of an extra supply of nutrients in the soil then rough calculations show that the milled dried compost in the soil is utilised several times more efficiently for sporophore production than the compost below the soil. That the effect is nutritional is also supported by the fact that the increases in yield are mainly due to the increased weight of the individual mushrooms.

The effect of the addition of organic nutrients on soil *p*H has been examined, but there is no evidence to suggest that the *p*H was altered sufficiently to exert any appreciable influence. Untreated soils were found to have a *p*H of 7.4 at casing, and additions of oxalate or dried compost did not lower it by more than 0.4 *p*H units.

Conclusions

1. Within the limits of the present experiments, in which relatively simple organic nutrients and milled dried compost were added to the casing soil, no detrimental effect on yield or numbers of mushrooms has been found. The apparent exception provided by the highest level of application of calcium oxalate can readily be explained as being caused by a high salt content. To this extent the results do not support the hypothesis that initiation of fruiting is related to the difference in nutritional status between compost and casing layer.

2. Experiments with milled dried compost added to the soil have produced considerable increases in yield, coupled with a tendency for increased weight of the individual mushrooms; the reasons for this have yet to be established.

3. In nearly all cases the addition of organic nutrients to the casing layer delayed the initial formation of pinheads, and cropping started a few days later than on untreated beds.

4. Further work is required on the nutritional aspects of the casing layer and on the practical possibilities of increasing yields by the addition of nutrients to it.

Addition of inorganic nutrients and salts to the soil

Experiment P.1 was designed as a 3 × 3 × 3 factorial experiment to examine the effects of three levels of nitrogen, phosphorus and potassium added to the casing soil. Ammonium sulphate, disodium hydrogen phosphate and potassium sulphate were the sources of nitrogen, phosphorus and potassium which, at three levels and in all possible combinations, gave a total of 27 treatments. These were arranged in three incomplete blocks each containing nine treatments. The experimental layout was replicated three times, using a total of 81 plant pots.

Each pot was cased with 1 Kg. of subsoil calculated on an oven-dry basis, to which was added 20 g. calcium carbonate. The three levels of each nutrient, namely, 0, 1.0 and 3.0 g. per pot, were added as the respective salts in 150 ml. water. To avoid differences in soil moisture content water was added, where necessary, so that each pot received 150 ml. whether salts had been applied or not. The main effects are summarized in Table V; interactions between the various nutrients were not significant and have accordingly been omitted.

TABLE V

Experiment P.1

Effect on fruiting of the addition of nitrogen, phosphorus and potassium to the casing soil

	Nitrogen added as ammonium sulphate (*g. per pot*)			Phosphorus added as disodium hydrogen phosphate (*g. per pot*)			Potassium added as potassium sulphate (*g. per pot*)			S. E. of means
	0	1.0	3.0	0	1.0	3.0	0	1.0	3.0	
Days, casing to 1st pinheads	18.5	24.1*	35.2**	25.2	24.0	28.7	24.6	26.0	27.2	±1.41
Days, casing to 1st picking	23.7	29.0	43.7	30.5	29.6	33.8	29.6	32.0	32.2	
Mean yields, g. per pot at 2 weeks ..	77.5	66.9**	63.0**	68.2	71.85	67.44	76.6	63.6**	67.3*	±2.20
Mean yields, g. per pot at 8 weeks ..	125.4	117.9	123.4	128.4	124.5	113.8**	131.0	116.7**	119.0*	±3.27
Mean numbers per pot at 2 weeks ..	5.7	3.7**	2.8**	4.2	4.5	3.6	4.9	3.8	3.7*	±0.39
Mean numbers per pot at 8 weeks ..	12.3	10.2*	8.7**	12.1	10.8	8.3**	11.7	10.1	9.4*	±0.64
Mean weight (g.) per mushroom at 8 weeks	10.2	11.6	14.2	10.5	11.5	13.7	11.2	11.5	12.7	

It was recognised that, as well as a possible nutrient or chemical effect, the addition of large quantities of salts to the soil would also have a physical effect; experiments P.2 and P.7 were accordingly designed to investigate any such effect. The salt chosen was sodium sulphate, on the assumption that sodium is of little or no nutritional value to the mushroom and that the sulphate ion is not toxic. In experiment P.2 four levels of sodium, namely 0, 5, 10 and 20 g. per pot, supplied as sodium sulphate, were applied to the soil in 200 ml. of solution. The experiment was laid out in five randomized blocks. A summary of the cropping is shown in Table VI.

TABLE VI

Experiment P.2

Effect on fruiting of sodium sulphate added to the casing soil

	Weight of sodium sulphate (*g. per pot*)				S. E. of means
	0	15.5	31.0	62.0	
Days, casing to 1st pinheads	18.4	20.8	24.8	45.8*	±6.3
Days, casing to 1st picking	23.4	29.2	31.6	52.8	
Mean yields, g./pot at 2 weeks	69.2	70.4	51.0	17.2	
,, ,, ,, 6 ,, ...	110.0	96.6	62.8	20.2	
,, ,, ,, 10 ,, ...	118.8	98.0	64.0**	20.8**	±8.7
Mean numbers per pot at 2 weeks	5.2	4.8	2.6	0.8	
,, ,, ,, 6 ,, ...	11.2	8.2	4.0	1.2	
,, ,, ,, 10 ,, ...	12.8	8.6**	4.2**	1.4**	±0.95
Mean weight (g.) per mushroom at 10 weeks	9.3	11.5	15.2	14.9	

Experiment P.7 also included several levels of sodium sulphate applied to the soil together with additions of this same salt to the compost at the time of spawning. There were three levels of sodium sulphate, namely, 0, 15 and 30 g. per pot, added to either soil or compost to give nine possible combinations in all; the different levels are designated C_0, C_1 and C_2 respectively when added to the compost and S_0, S_1 and S_2 when applied to the casing soil. The sodium sulphate was added to the compost by turning out the contents of each pot and sprinkling the salt from a container with a perforated top. Treatment of the soil was carried out immediately after casing, as described previously, 150 ml. of liquid being applied to each pot. Table VII shows the details of the treatments and cropping data.

TABLE VII

Experiment P.7

Effect on fruiting of sodium sulphate added to soil and compost

	Weight of sodium sulphate added to soil (*g. per pot*)			Weight of sodium sulphate added to compost (*g. per pot*)			S. E. of means
	S_0 0	S_1 15	S_2 30	C_0 0	C_1 15	C_2 30	
Days, casing to 1st pinheads	21.2	24.7	41.1**	26.0	32.0	28.8	±2.0
Mean yields, g. per pot at 2 weeks ..	77.4	59.4**	39.8**	79.4	59.6**	37.6**	±3.8
,, ,, ,, 4 ,, ..	117.0	84.2**	54.0**	116.5	84.3**	55.4**	±5.1
Mean numbers per pot at 2 weeks ..	9.1	5.3**	2.8**	7.5	6.0	3.8**	±0.79
,, ,, ,, 4 ,, ...	15.0	7.8**	3.8**	11.7	8.9*	6.0**	±0.90
Mean weight (g.) per mushroom at 4 weeks	7.8	10.8	14.1	10.0	9.5	9.2	

Note: Subdivision of the treatment sums of squares into linear and quadratic components shows that salt added to either soil (S) or compost (C) produces a significant ($P<0.01$) linear response. The linear C×S interaction is also significant ($P<0.01$).

Discussion of results

As may be expected, the addition of salts to the casing had some effect on soil *p*H. With one exception, however, the *p*H values of the treated soils were within 0.6 *p*H units of that of the untreated soil. This represents a range of *p*H from 6.8 to 7.9, within which the effect on yield is not expected to be appreciable.

Experiment P.1 was designed originally on a nutritional basis, and the main effects due to the additions of three levels of each nutrient are shown in Table V. Consideration of Figures 1 and 2, however, suggests that the effects were related mainly to the quantities of salts added rather than to any specific nutritional factor.

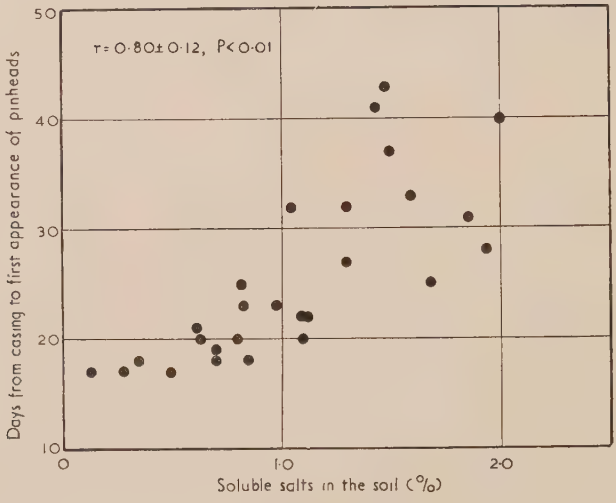

FIG. 1

Experiment P.1. Relation between onset of fruiting and soluble salts in the casing soil after treatment; each point is the mean of three replicates.

Only the addition of nitrogen significantly delayed the appearance of the first pinheads, but Figure 1 shows that when the additions are considered in terms of soluble salts in the soil there is a correlation ($r=0.80\pm0.12$, $P<0.01$) between soil salt content and the time taken for pinheads to appear. This is confirmed in Tables VI and VII, in which it can be seen that additions of sodium sulphate significantly delayed the appearance of pinheads.

Tables VI and VII also show that the addition of sodium sulphate to the casing soil had a highly significant effect on the numbers of pinheads formed, and the mean weight of mushrooms per pot was also reduced, though not to such a great extent; both effects were proportional to the amount of salt added. At the higher salt levels fewer pinheads were formed, but they developed into much larger mushrooms. In experiments P.2 and P.7 the mushrooms obtained at the highest level of soluble salts were over 50% heavier than those from the untreated pots. Presumably the smaller numbers of developing pinheads on the pots to which salt has been added are subject to less competition for the supply of available food in the compost, and are thus able to develop into larger, heavier mushrooms. Despite this, the effects of additions of sodium sulphate were such that although each mushroom tended to be larger the total weight produced was lower than that from the untreated pots. In experiment P.1, the same pattern of behaviour is readily seen, increasing salt content resulting in fewer pinheads being formed ($r=-0.695\pm0.14$, $P0<0.01$) and the mean weight of the individual mushrooms being increased.

Figure 2 shows, in fact, that the mean weight of the mushrooms was more than doubled at the 2% level of soluble salt. Additions of nitrogen as ammonium sulphate reduced the numbers of pinheads, but those which did form and develop were heavier and no decrease in total weight per pot resulted after 8 weeks' cropping although after only 2 weeks yields were significantly lower. The total weight per pot was also significantly reduced by the addition of potassium sulphate at both levels after 2 and 8 weeks' cropping and by the highest addition of disodium phosphate after 8 weeks' cropping.

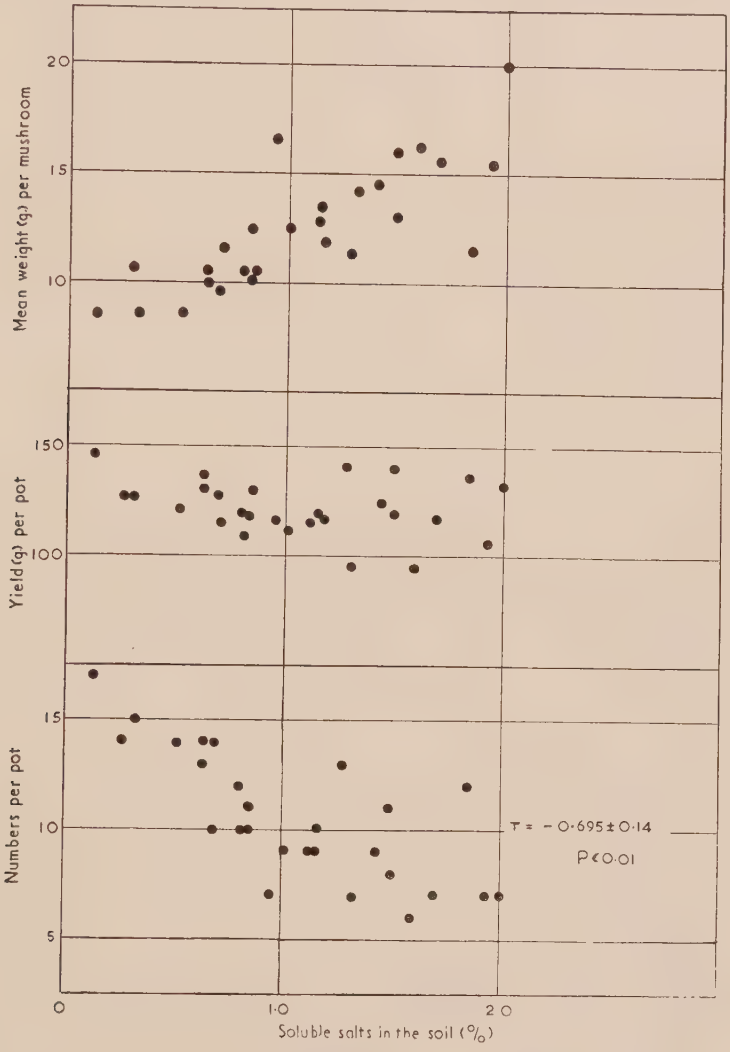

FIG. 2

Experiment P.1. The relation between fruiting and soluble salts in the casing soil after treatment.

The adverse effect of the highest level of calcium oxalate on numbers of mushrooms has been mentioned previously and attributed to salt concentrations. The oxalate used for this experiment was prepared in the laboratory and, despite extensive washing, was subsequently found not to be free from soluble constituents. At the lower levels of addition of oxalate the amount of soluble material present would have practically no effect but, at the highest level of calcium oxalate, would correspond to the addition of 0.7% soluble salts. This is just above the point at which the physical effects of salt concentration become apparent, and the decrease in numbers of mushrooms produced at this level of oxalate should probably be attributed to this cause.

In experiment P.7 additions of sodium sulphate were made to the compost at spawning as well as to the soil at casing. The main effects of the addition of salts to the soil have already been discussed. In the compost, however, the effect of sodium sulphate followed a rather different pattern. Table VII shows that there was no significant effect on the appearance of the first pinheads, but both numbers and total weight of mushrooms per pot were reduced without any significant change in the mean weight of the mushrooms. Addition of sodium sulphate, therefore, merely reduced the general level of productivity of the compost and adds confirmation to the work of Pizer (5) on the adverse effect of sodium and potassium ions in the compost.

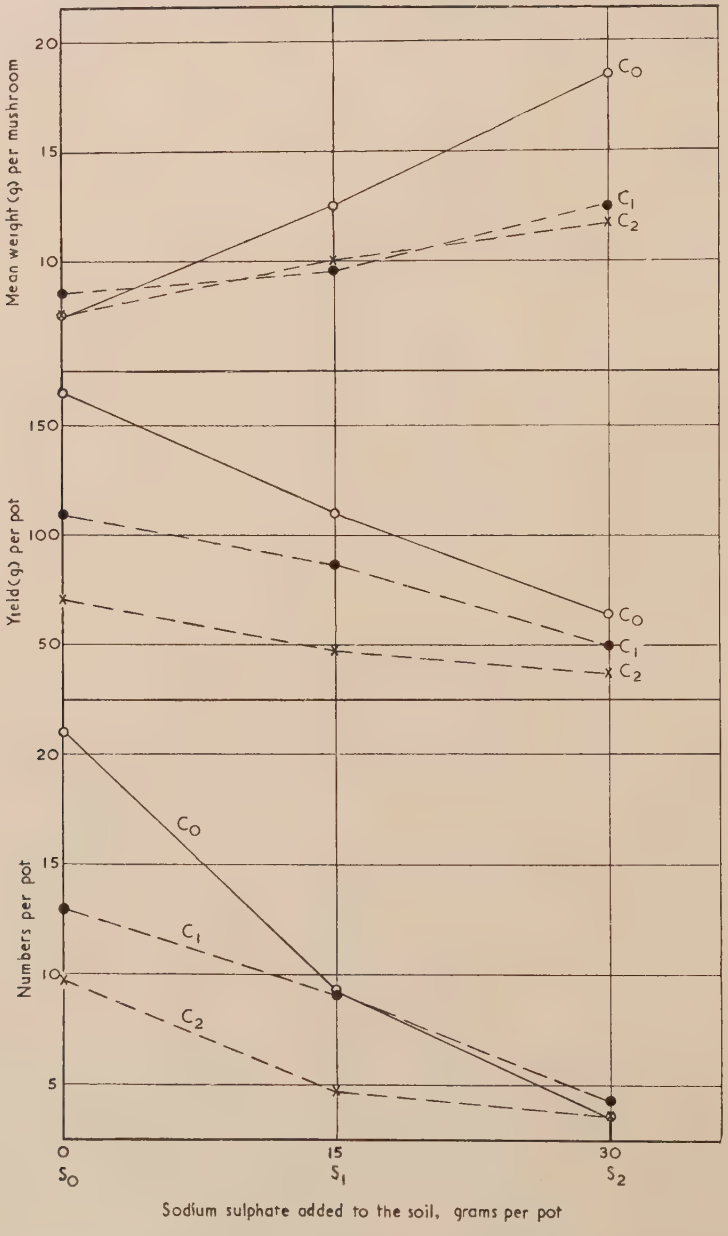

FIGURE 3
Experiment P.7. The effects on fruiting of additions of sodium sulphate to the compost (C) and casing soil (S).

The significant interaction between the addition of salt to the compost and to the soil is of interest, as shown in Figure 3. The marked effect of added salts in the soil upon numbers and weight of mushrooms produced is much reduced at high levels of soluble salts in the compost.

The effect of increasing the soluble salt content of the casing soil has been shown consistently in three separate experiments, though the possibility that some ions may have specific nutritional or toxic effects must not be overlooked. As the analytical work is not yet complete, discussion of the possible mechanisms involved must be limited. It is known that high concentrations of soluble salts in the soil have serious effects on green plants, mainly by disturbance of water absorption by the roots. The soluble salt contents of some of the treated casing soils in these experiments were over 3% and *p*C values below 2.0 were obtained. Although there was a considerable effect on fruiting, at no time were any abnormal mushrooms observed.

Apart from helping to shed light on the factors involved in fruiting, the use of inorganic salts to influence numbers and mean weight of mushrooms may be of some practical importance. Many growers are troubled by crops of large numbers of small mushrooms, which require more labour to pick and are easily damaged. A means of reducing the number of mushrooms without appreciably lowering the total weight of crop would be of considerable value. The early claims of growers that the quality of mushrooms is improved by the application of common salt to the casing layer now have a measure of experimental support in that fewer but larger mushrooms have been produced in the present investigations by similar means.

From the analytical data available so far, full discussion of the effect of soluble salts in the compost and casing under normal growing conditions is not possible. Several composts, both of horse manure and synthetic, have been examined and the soluble salts extracted have been found to range from 2—7%, on a dry matter basis, at the time of filling. It is reasonable to assume that continuous evaporation of water from the surface of the casing layer will cause some upward movement of salts from the compost to the casing during the cropping period. Evidence of this was provided by the experiments in beakers referred to earlier; before use the soil had a *p*C value of 3.8 but at the end of the experiment the *p*C value of soil from beakers which had received no additions of salts was about 2.9.

Determinations of soluble salts in the pot experiments have confirmed this movement, changes in soluble salt concentration from 0.12 — 0.14% at the time of casing to 0.35 — 0.50% after cropping being found. Further evidence of transfer of salt between compost and soil may be seen in Table VIII. At the S_0 and S_1 levels of salt in the soil there is an increase in the soluble salt content of the soil during the cropping period. This increase in salt content tends to be greater where salt was added to the compost. At the highest level of salts in the soil (S_2) there appears to have been a loss of salt during cropping, presumably to the compost, though analyses of a few compost samples failed to give a clear indication of either gain or loss of salts. This, however, is not surprising as the amount of soluble salts extracted from the compost at the end of cropping is affected by the extent to which the compost has decomposed. As the latter is to some extent related to yield of mushrooms, differences due to salt transfer would be difficult to detect.

It is thus clear that considerable movement of salts from compost to casing layer occurs, and further work must be carried out to discover whether it is of practical significance. It is also of interest to investigate the nature of the salts which accumulate in the soil, and whether the accumulation is due to physical processes or to the activity of the mushroom mycelium. Analysis of soils from the early beaker experiments showed little or no increase in nitrogen but relatively large increases in potassium in the soil during the cropping period.

TABLE VIII

Changes in the concentrations of soluble salts in the casing soil during cropping

Treatment	Soluble salt % per 100 g. dry soil		Gain or Loss
	At casing	At emptying	
S_0 C_0	0.12	0.34	+0.22
S_0 C_1		0.39	+0.27
S_0 C_2		0.50	+0.38
S_1 C_0	1.38	1.74	+0.36
S_1 C_1		1.82	+0.44
S_1 C_2		1.94	+0.56
S_2 C_0	2.86	2.52	−0.34
S_2 C_1		2.35	−0.51
S_2 C_2		2.49	−0.37
S.E. of means	±0.04	±0.08	

Note: The data are taken from Experiment P.7 (Table VII), in which sodium sulphate was added at three levels to the soil (S_0, S_1 and S_2) and to the compost (C_0, C_1 and C_2).

Conclusions

1. The addition of inorganic salts to the casing soil had highly significant effects on fruiting. The appearance of pinheads was delayed, and the numbers and total weight of mushrooms reduced, but the mean weight of the mushrooms was increased. The effects appear to be substantially proportional to the amounts of salt added. This may be of considerable practical importance in solving the problem of excessively small mushrooms.

2. There appeared to be little or no specific nutritional effect when salts containing nitrogen, phosphorus or potassium were added; the effects appear to be due mainly to the amount of soluble salts in the soil, though the possibility of some ions having a specific nutritional or toxic effect cannot be excluded.

3. Observations by growers that the addition of salts to the casing layer improves quality are given some support by the increased mean weight of individual mushrooms obtained in these experiments.

4. The significance of these results in relation to the mechanism of fruiting and from the practical aspects of yield and quality requires further investigation.

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IV. PLANT BREEDING

by

L. A. DARBY

Cucumber and tomato variety trials were carried out in 1956, mainly utilizing material already available at the Institute. These trials served primarily for the introduction of better experimental techniques, and for the detection of some of the large cropping gradients inherent in the trial glasshouses.

Cucumber

Five F_1 hybrids between existing commercial varieties, together with the reciprocal hybrids of four, were compared with one commercial variety. Thus there was no chance to compare the hybrids with their parents in order to ascertain either the pattern of inheritance, or any expression of heterosis which might occur, of desirable commercial characters in English glasshouse cucumbers.

The trial was sown on 9/1/56 and planted out on 15/2/56. The experimental design was a Graeco-Latin square with 5 replicates, and there were 9 plants per plot spaced at 2ft. Twice-weekly cutting began on 16/3/56, and recording continued until 27/9/56 when the activities of large bee populations prevented any further accurate work. Temperature control was difficult, especially during propagation when it was sometimes impossible to maintain adequate night temperatures. Attacks of mildew and red spider were limited by suitable chemical control measures.

The early and total yields for the five plots of each variety are shown in Table I, and fruit grading in Table II.

TABLE I

Cucumber variety trial: early and total yields.

Genotype	Early crop			Total crop		
	Number of fruit	Weight of fruit	Mean Weight	Number of fruit	Weight of fruit	Mean weight
		oz.	*oz.*		*oz.*	*oz.*
8	435	6,352	14.6	3,962	62,512	15.8
(1	467	6,816	14.6	4.099	64,992	15.9
2)	457	6,848	15.0	3,874	62,000	16.0
(3	513	8,944	17.4	3,586	63,104	17.6
9)	492	8,608	17.5	3,450	60,288	17.5
(4	462	7,328	15.9	3,696	62,816	17.0
10)	470	7,520	16.0	3,792	63,872	16.8
(5	518	8,416	16.3	3,646	59,936	16.4
6)	422	7,120	16.9	3,626	61,792	17.0
7	519	8,064	15.5	3,563	56,400	15.8
L.S.D.	53	878		249	3,737	

Notes: 1. The early crop is that for the first four weeks.
2. Reciprocal hybrids are bracketed.
3. Lowest significant difference values are for P=0.05.

TABLE II

Cucumber variety trial: fruit grading

Geno-type \ Grade	Percentage of fruit per market grade								
	9	10	11	12	13	14	16	18	20
8				7	24	32	24	10	3
1			1	6	24	35	23	8	3
2			1	5	22	35	24	10	3
3		1	3	15	30	23	8	9	11
9		1	2	16	29	25	10	6	11
4	1	4	6	21	28	24	10	4	2
10		4	9	26	32	16	10	3	0
5		2	8	21	31	19	11	4	4
6		3	3	21	32	19	12	5	5
7		1	2	15	27	33	14	6	2

Note: Grading data are based on a total of 1,950 fruits harvested in the period 13–20/7/56.

Tomato

Twenty-five genotypes were tested for yield and fruit quality in a 5×5 partially balanced lattice with 4 replicates. There were 20 plants per plot. Seeds were sown on 13/1/56, and the plants were planted in borders on 6/3/56. Planting distances were 18 and 27 inches between alternate rows, and 13 inches within the rows. Twice-weekly picking began on 24/5/56, and the crop was cleared on 8/10/56.

Temperature control during propagation was difficult, and the plants received differential illumination from the early morning sun, due to shadows cast by another propagating house. The trial suffered extensive damage from wireworm, tobacco mosaic virus, *Botrytis*, wilt diseases and *Cladosporium*.

Fruit of uniform colour was graded by the Tomato and Cucumber Marketing Board standards for "Pink, Pink and White, White, Blue, and Blue and White," plus two extra grades. These were "Chats" for fruit smaller than "Whites," and "Roughs" for the remnant of badly shaped fruit. Non-uniformly coloured fruit was graded in accordance with the scheme described in the Plant Physiology Department's report, but with one small modification. NUC/A grade was only for fruit in which the green area extended round at least 75% of the circumference of the calyx.

The early and total yields for the four plots of each variety are shown in Table III; fruit grading and non-uniformly coloured fruit are shown in Table IV.

TABLE III

Tomato variety trial; early and total yields

Genotype	Early crop	Total crop
	oz.	*oz.*
1	1,086	8,141
2	1,003	9,232
3	1,034	7,601
4	1,724	10,465
5	1,448	8,645
6	1,045	9,605
7	1,184	7,867
8	952	9,612
9	1,635	9,683
10	884	10,348
11	1,000	7.908
12	724	10,672
13	1,713	9,094
14	704	9,670
15	1,851	9,253
16	1,542	9,932
17	1,314	10,281
18	1,636	8,827
19	1,366	9,428
20	817	9,392
21	875	8,993
22	1,090	10,038
23	1,379	10,777
24	1,473	10,387
25	1,863	10,740
L.S.D.	285	1,210

Note: Lowest significant difference values are for P = 0.05.

TABLE IV

Tomato variety trial; fruit grading (% total crop)

(i) *Uniformly coloured fruit*

Genotype	Uniformly coloured fruit							Non-uniformly coloured fruit
	Pink	Pink/ White	White	Blue	Blue/ White	Rough	Chats	
1	1	48	23	0	1	0	4	23
2	9	42	13	0	0	0	2	34
3	13	14	3	9	4	10	1	46
4	17	27	4	4	2	4	0	42
5	8	38	10	2	1	3	1	37
6	14	42	9	1	1	1	2	30
7	3	27	10	2	4	15	2	37
8	16	37	7	1	2	0	1	36
9	5	40	13	1	1	6	2	32
10	12	41	8	1	1	0	1	36
11	4	45	23	0	0	0	5	23
12	18	30	3	10	3	6	1	29
13	5	47	13	4	1	3	1	26
14	7	11	2	4	1	7	0	68
15	11	31	5	4	2	10	1	36
16	17	42	8	1	2	0	1	29
17	14	46	6	1	1	1	1	30
18	5	40	11	1	1	2	2	38
19	15	19	2	9	4	7	0	44
20	6	9	2	3	2	5	0	73
21	26	41	6	2	2	0	1	22
22	14	24	4	6	2	5	1	44
23	18	31	4	4	2	4	1	36
24	15	42	7	2	1	3	1	29
25	18	17	2	10	3	14	0	36

(ii) *Non-uniformly coloured fruit*

Genotype	Uniformly coloured fruit	Non-uniformly coloured fruit				
		A	B	C	D	Z
1	77	3	2	10	0	8
2	66	3	5	18	0	8
3	54	1	8	16	1	20
4	58	5	7	16	0	14
5	63	5	5	12	1	14
6	70	4	4	17	0	5
7	63	3	4	10	0	20
8	64	3	4	20	0	9
9	68	5	4	8	0	15
10	64	3	5	19	0	9
11	77	5	2	9	0	7
12	71	6	4	9	0	10
13	74	3	4	7	0	12
14	32	4	9	34	0	21
15	64	4	6	8	0	18
16	71	5	4	11	0	9
17	70	4	3	15	0	8
18	62	5	5	10	0	18
19	56	3	7	11	0	23
20	27	4	9	39	0	21
21	78	4	3	9	0	6
22	56	3	6	19	0	16
23	64	4	5	19	0	8
24	71	4	6	10	0	9
25	64	4	5	16	0	11

V. PLANT PATHOLOGY

1. DIDYMELLA STEM ROT OF THE TOMATO

by

P. H. WILLIAMS & JUDITH HACK

It has been previously reported (Williams & Hack, 1954) that when unsterilized soil is inoculated with spores of *Didymella lycopersici* the fungus does not become established, and if tomato plants are subsequently planted in such soil the majority remain healthy. In sterilized soil similarly inoculated, however, the fungus appears to grow freely and most of the tomatoes subsequently planted become diseased. Experiments carried out in a glasshouse at Cheshunt suggest that sterilized soil recovers its immunity to invasion by *D. lycopersici* in about twelve months.

Laboratory experiments to investigate this phenomenon have been carried out over a period both at Cheshunt and Littlehampton, soil from Cheshunt being brought to Littlehampton for the sake of continuity. The following report summarises the work to date.

Direct observation of D. lycopersici spores on sterilized and unsterilized soil

Thin layers of unsterilized soil were applied to slides coated with water agar and inoculated by adding a small quantity of spore suspension. The spores could be easily seen between the soil particles and observations made on their fate over a period of five to six weeks. It was found that the spores either disappeared or, if they germinated, the germ tubes remained short and soon ceased growth. When similar slides were autoclaved, however, spore germination was normal and the fungus grew and eventually sporulated.

During this year an attempt was made to obtain permanent records of the behaviour of spores in unsterilized soil. Coverslips were used in place of slides and, after inoculation, were inverted over Van Tieghem cells. Suitable fields containing spores were chosen and kept under the microscope for periods of up to two weeks. Drawings or photographs were made at intervals.

As in previous experiments, nothing could be seen to account for the death and disappearance of the spores. Several workers have shown that fungus mycelium may be destroyed by bacteria or other fungi but nothing suggesting that this takes place in the case of *D. lycopersici* has been observed.

Toxic effect of the soil solution on D. lycopersici spores

Several methods have been employed to test the effect of the soil solution on the germination of spores of *D. lycopersici*. Water extracts of unsterilized soil and soil solution displaced by alcohol, both sterilized by filtration, did not inhibit germination. During the past year another method was tested. Wet unsterilized soil was packed around a sterilized filter candle (L7 or L9) and the soil solution was sucked into a sterile container. Spores germinated in this solution as well as, or better than, in distilled water.

Relation of soil micro-organisms to survival of D. lycopersici spores

The effect of glucose on the soil microflora and survival of D. lycopersici

Dobbs and Hinson (1953) have reported that after the addition of glucose to unsterilized soil spores germinated which did not germinate in unamended soil. West and Hildebrand (1941) also found that the bacteriological balance in soil was so altered by the addition of glucose that one month later strawberry root rot was much less severe.

Glucose was added to unsterilized soil at rates of 1% and 5% one month before inoculation with spores of *D. lycopersici*. Unamended soil was inoculated at the same time. After a further month's incubation the number of spores surviving in all three soils was determined.

Where 1% glucose was added, the number surviving (18%) was approximately the same as in unamended soil. With the addition of 5%, however, about 66% survived.

Counts of other soil micro-organisms showed that the addition of glucose led to an increase in their numbers. The number of actinomycetes was not much higher with 5% than with 1% glucose, but bacteria and fungi showed big increases. There was, therefore, no direct connection between the actual numbers of micro-organisms and death of spores but the balance of species may have been changed by the higher level of glucose, resulting in partial elimination of organisms antagonistic to *D. lycopersici*. Alternatively there may be a direct effect on *D. lycopersici* causing growth of those spores which survived and hence a higher count after four weeks' incubation.

Inoculation of sterilized soil with soil organisms

It has been shown in a previous experiment that steamed soil remains susceptible to infection by *D. lycopersici* for three to four months but becomes almost immune in twelve months. It seemed possible that the process was complex and the organisms not necessarily specific, some requiring a long incubation period to render the soil toxic.

A number of flasks of soil were sterilized and divided into thirteen series. These were inoculated with fungi, bacteria and actinomycetes either singly or in combination. To one series a water suspension of unsterilized soil was added, and to another unsterilized soil. One series was left untreated as a control. The flasks were incubated for different periods up to nine months. At intervals flasks from each series were removed from the incubator and the soil tested for its power to inhibit *D. lycopersici* by adding a known number of spores and plating four weeks later.

None of the organisms or combinations of organisms tested had any effect on the germination and growth of *D. lycopersici*. When, however, a suspension of unsterilized soil or 5% of unsterilized soil had been added, survival of spores was reduced to 50% after two weeks and inhibition increased with time until after nine months it was complete.

Selective destruction of soil organisms

It appeared that some light might be thrown on the nature of the inhibiting organisms by steaming soil for different periods thus eliminating different members of the soil microflora.

Soil was steamed in a box with a grid in the bottom and samples removed at intervals after the whole had reached 100°C. and placed in sterile flasks. As this method required rather a large quantity of soil, other methods were tested. The most satisfactory was to place about 200 g. of soil in a beaker at the bottom of which was a small perforated copper coil. The soil was heated to 100°C. for varying periods by passing steam through the coil and then placed in sterile flasks. Soil steamed by this method tended to become very wet but results were comparable to those obtained by the first method.

The degree to which soil organisms were destroyed increased as the heating was prolonged. Between 30 seconds and 10 minutes the numbers of bacteria, which were reduced by the treatment, increased on subsequent incubation of the soil but did not regain their pre-steaming level. All fungi were destroyed by steaming for 30 seconds and actinomycetes were drastically reduced and showed little recovery. When spores of *D. lycopersici* were added to soils steamed for these periods, they were not destroyed.

When the soil was heated to 100°C. and immediately placed in flasks, fungi were greatly reduced in numbers and did not increase on incubation. Bacteria and actinomycetes were also greatly reduced but increased on incubation to levels well above those in untreated soil. Soil treated in this manner remained toxic to spores of *D. lycopersici*.

The results of this experiment suggest that the soil fungi have no responsibility for the toxicity of unsterilized soil to *D. lycopersici*, since they were eliminated or greatly reduced. It would seem that bacteria and actinomycetes are more likely to be the source of the toxicity.

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2. CUCUMBER MILDEW

by

OLWEN M. STONE

Owing to the continued lack of suitable glasshouse accommodation for the isolation of plants for mildew work, the first problem was the development of a suitable method for experimentation on mildews in the laboratory. The use of seedlings growing in test-tubes was suggested, a method which has been used by several workers with other pathogens and hosts.

Preliminary experiments were set up to discover the best type of container and rooting medium for use with cucumber. Finally, it was decided that large tubes 10in. x 1½in. were the most suitable as they were large enough to allow growth of the plant for a considerable time, up to about eight weeks, and were also of a suitable diameter for examination under the low power binocular microscope, so that the plants could be inspected without removal from the tubes. The rooting medium used was a coarse sand or gravel as used on the nursery, washed before use to remove the dusty part which otherwise tended to obscure the sides of the tubes.

The following technique has been used for the work. Tubes are filled with about 60 g. of sand, plugged and sterilized. The seed is surface sterilized by shaking in bleaching powder (calcium hypochlorite) solution 7% for 15 minutes, and one seed is placed in each tube by means of sterile forceps. 15 ml. of a standard nutrient solution, also previously sterilized, is then added to each tube, and the tubes are placed in an incubator at 25°C. for 48 hours. After this, the tubes showing germinating seeds are hung on wires in a north window. The plants are usually large enough to inoculate after 7-10 days. Inoculation is carried out by means of a fine camel hair paint brush, sterilized by immersing in industrial spirit and allowing this to evaporate before use.

Spores from the source of inoculum are collected by touching with the brush and transferred to the test plant by gently brushing against the leaf or cotyledon to be infected. It has been generally found that infection of cotyledons is most suitable because they are less hairy than the true leaves, and hairs tend to obscure the view of the infection. For single spore cultures, the spores are picked up on the tip of an eye-lash, embedded in paraffin wax on a platinum loop and sterilized in the same way as the brush. Infection can usually be seen about seven days after inoculation, both to the naked eye and under the microscope.

Cultures in tubes can be kept alive for a period of one to two months before sub-culturing. This period tends to be shorter in the summer when the higher temperature probably has some effect on the growth of the host. After about one month from planting, the seedlings are usually watered with 5 ml. of the standard nutrient solution to prevent drying out of the rooting medium.

During the course of the year a number of isolates of cucumber mildew have been collected from various sources and it is hoped that it will be possible to discover whether or not there are strains of the fungus present in this material.

All stock cultures have been grown on the variety Butcher's Disease Resister, to ensure uniformity of host. There has been no sign of variation in virulence of any isolates on this host.

Various other plants have also been grown in tubes in the same way as the cucumber and reference will be made to these later. It has been found that some plants are less suitable for tube growth, probably because they normally grow under dry conditions, whereas the conditions in the tubes are always moist.

Problems considered during the year

Resistance to cucumber mildew within the family Cucurbitaceae.

With the collaboration of the Plant Breeder, Mr. Darby, a collection of various Cucurbitaceae was made from as many sources as possible and tested for resistance to powdery mildew. Preliminary tests were carried out in tubes. Two tubes of each type were grown and the young plants inoculated, as soon as the cotyledons were sufficiently expanded, with spores from a stock culture of mildew from cucumber. The number of plants of each type tested was small, but had to be limited owing to the large number to be tested and the relatively small space available. In addition to the test tubes, a single specimen of each type was planted in the cucumber houses, most in pots, a few in the beds. The incidence of mildew on these was recorded during the season.

The results are shown in the following table:—

MILDEW SUSCEPTIBILITY IN CUCURBITACEAE

	Tube Reaction	*Greenhouse Reaction*		
		Leaf	*Stem*	*Fruit*
Benincasa cerifera	**	—	—	—
Bryonia alba	**	*	**	—
B. dioica	**	**	**	—
Bryonopsis laciniosa	**	—	—	—
Citrullus colocynthoides	**	*	**	—
Cucumis sativus:				
var. Bedfordshire Prize Ridge	**	**	**	—
„ Butcher's Disease Resister	**	***	**	**
„ B.D.R. X Rochford's Market	**	**	**	—
„ Gherkin	**	**	**	—
„ Long Green Improved	**	**	**	—
„ New Japanese Climbing	**	**	**	—
„ Stockwood Ridge	**	**	**	—
C. melo:				
var. Best of all	**	***	**	—
„ Cantaloup Prescotts	**	***	**	—
„ *flexuosus*	**	***	**	—
„ from Portugal	**	**	**	—
Cucumis africanus	**	—	—	—
C. agrestis	**	**	**	—
C. anguria	**	*	—	—
C. dipsaceus	**	*	—	—
C. metuliferus	**	**	**	—
C. myriocarpus	**	**	**	—

	Tube Reaction	Greenhouse Reaction		
		Leaf	Stem	Fruit
Cucurbita pepo:				
var. Apple-shaped gourd	**	***	**	—
„ Egg-shaped gourd	**	***	**	—
„ Orange gourd	**	***	**	—
„ Pear-shaped gourd	**	***	***	—
„ Spoongourd	**	***	***	—
„ Vegetable Marrow Cocozalle	**	***	**	—
„ Vegetable Marrow Green Bush	**	***	**	—
Cucurbita maxima:				
var. Hundredweight gourd	**	**	**	—
„ Turban gourd	**	***	**	—
C. moschata:				
var. Squash Banana	**	***	**	—
„ Squash Uconn.	**	N.T.	N.T.	N.T.
Cucurbita ficifolia (=*C. melanosperma*)	**	**	**	—
C. foetidissima	**	**	**	—
C. mixta	**	**	**	—
C. palmata	**	**	**	—
Cyclanthera explodens	**	—	—	—
C. pedata	**	—	—	—
Ecballium elaterium	*	—	—	—
Echinocystis lobata	**	—	—	—
E. wrightii	**	—	—	—
Lagenaria leucantha depressa	**	**	**	—
Lagenaria leucantha longissima	**	**	**	—
L. sp. Hercules club gourd	**	***	**	—
L. sp. Siphon or Dipper gourd	**	**	**	—
Lagenaria vulgaris	**	**	**	—
Luffa acutangula	N.T.	—	—	—
Luffa aegyptica	—	—	—	—
Melothria pendula	**	**	**	—
M. scabra	**	**	**	—
Momordica balsamina	**	—	—	—
M. charantia	**	—	—	—
M. charantia var. *muricata*	**	—	—	—
Thladianthia dubia	**	**	**	—
Trichosanthes anguina	**	**	**	—

*** severe infection.
** moderate infection.
* slight infection.
— no infection.
N.T. No test.

It can be seen that only the species of *Luffa* are completely resistant to mildew. Altogether, about twenty tubes of *L. aegyptica* were tested and no infection could be obtained. Of the others, *Ecballium elaterium* was only slightly infected in the tubes after three attempts and not at all in the greenhouse.

Certain species which were infected experimentally in the tubes remained free from mildew in the glasshouse. The glasshouse was shared by other workers, and it was impossible to maintain the warm, moist conditions used in cucumber growing. It is possible that the plants remained healthy because conditions were unsuitable for infection. It is proposed to grow them under cucumber conditions in the coming year to test this supposition.

Other hosts for cucumber mildew

A study of the literature on powdery mildews in general shows that there is a considerable divergence of opinion on the specificity of these fungi. Some workers, for example Blumer (1), maintained that the powdery mildews are highly specialised as to host, and that a mildew occurring on one species will be specific to that species or to a small group of related species. At the opposite extreme, Hammarlund, in 1945, proposed a new species, *Erysiphe polyphaga*, to include a large

number of previously described *Oidium* species, and published experimental results showing that mildew from *Kalanchoe* sp. could infect 62 different species of plants, including cucumber and several ornamentals, and produce typical mildew symptoms.

This question is linked up with the problem of how cucumber mildew survives the winter in the absence of cucumbers. The perfect stage has only been recorded twice in Britain in the last fifty years, so that it does not seem to be a likely source of re-infection in the spring. The asexual spores will not survive for more than a few days off the plant or on detached portions of the plant. It therefore seems possible that the fungus overwinters on one or more alternate host plants.

This problem has been considered from two aspects. First a selection of plants unrelated to the cucumber has been grown in tubes and inoculated with mildew from cucumber. Secondly, mildews found growing on wild and other plants on the nursery have been used as sources of inoculum for cucumber plants in tubes. Experiments so far have been carried out on small numbers of plants, and larger scale experiments are planned for the coming year.

The results of the small scale experiments are set out below.

(i) *Inoculation of unrelated plants with mildew from cucumber*

Positive infection was recorded when chains of conidia were visible on the inoculated plants. The following plants showed positive infection:—

Chrysanthemum coronarium
C. carinatum
Eucalyptus globulus
Lactuca alpina
Linum usitatissimum
Picris hieracioides
Ricinus communis
Senecio vulgaris
Sonchus arvensis

The following plants did not show infection:—

Antirrhinum orontium
Eucalyptus citriodorus
E. rostrata
Hyssopus officinalis
Kalanchoe blossfeldiana
Sedum spurium
Taraxacum officinale

(ii) *Inoculation of other mildews onto cucumber*

Positive infection was again recorded where spore chains were visible. The inoculations of mildews from the following naturally infected hosts gave positive infection on cucumber:—

Sonchus sp. (identified from perfect stage as *Erysiphe cichoracearum*)
Senecio vulgaris
Ranunculus repens (identified from perfect stage as *Erysiphe nitida*)

Mildew from cucumber inoculated onto *Linum usitatissimum* and *Chrysanthemum carinatum* gave positive infection when inoculated back onto cucumber.

Mildews from the following hosts did not infect cucumber. The species of mildew concerned is given where a perfect stage was found in association with the infection, otherwise it may be assumed that only the *Oidium* stage has been found so far. The four *Oidium* stages given were all found in the glasshouse and the perfect stages were found outside.

Aster novi-belgii (*E. cichoracearum*)
Plantago major (*E. cichoracearum*)
Picris hieracioides (*E. cichoracearum*)
Taraxacum officinale (*Sphaerotheca fuliginea*)
Streptocarpus sp.
Statice sp.
Dianthus sp.
Chrysanthemum sp.

Larger scale experiments have been started with some of the mildews from other hosts inoculated onto cucumber, in order to discover whether repeated sub-culturing of the fungus on cucumber can increase its virulence.

The identity of cucumber mildew

A problem associated with the host range of cucumber mildew is the accurate identification of the causal species. It is generally agreed that conidial measurements are not reliable as a character for identification of species, since the condition of the host may affect the conidial size. Therefore it is advisable to find the perfect stage of the mildew before attempting to name the causal fungus. Both *Erysiphe cichoracearum* and *Sphaerotheca fuliginea* have been recorded on the Cucurbitaceae (2, 4) and since both these fungi occur on other hosts in this country, either or both may be the cause of cucumber mildew.

Experiments and observations so far have given no absolutely definite indication of the identity of the fungus. The mildew from *Sonchus* was identified as *E. cichoracearum* and produced sparse spore chains on cucumber, but the infection did not maintain itself in the culture. The mildew from *Ranunculus* was identified as *E. nitida*, a species close to *E. polygoni*. Experiments with this isolate are not yet complete. The only isolate of *Sphaerotheca fuliginea* tested (from *Taraxacum*) did not produce infection on cucumber.

From observations of the mildews found during the year, it seems that the state of the host plant influences the production of the perfect stage. On *Sonchus*, the perithecia were produced on old plants which had been kept dry in a warm greenhouse and which were also heavily infested with white fly, aphid, and red spider mite. The perfect stage appeared when the plants were in a decidedly moribund condition. Perithecia are rare on this host under natural conditions.

Many workers have noted the increased occurrence of perfect stages of powdery mildews associated with conditions adverse to the host. Thus more perfect stages are recorded in hot, dry summers and at the onset of autumn. Temperature, humidity and day length have all been suggested as the important factor.

It has been observed that the mildew in tubes showed increased conidial production at lower temperatures (45–50°F. compared with 50–60°F.) The conditions were not sufficiently constant to attach much significance to this, but further experiments could clarify this.

Spore trapping

During the year, a Hirst Spore Trap was obtained and preliminary catches were made. The trap was first used outside in order to find out if any mildew spores were present in the air around the glasshouses. In a series of catches from late March over a period of two months no mildew spores were ever found. During this period there was no crop nearby heavily infected with mildew, although mildew was already present in the cucumber houses. It has not been decided why no spores were found. Hirst's experiments were carried out in fields heavily infected with cereal mildews where the spore incidence was very high, and it may be that spores were present in such small numbers in the air at Littlehampton that none were picked up on the slides. Two catches were made in the greenhouses, and again results were disappointing; spores were caught, but in very small quantities. This may have been due to the lack of wind or air currents in the houses and perhaps to the fact that the trap was set up at ground level and not raised.

Work on other mildews

Since the work on one mildew naturally leads to investigation of all sources of mildew on the nursery, a few observations have been made on chrysanthemum and carnation powdery mildews

which are both present on the Institute's nursery. Unlike cucumber mildew, very little work has been carried out by other workers on the biology of these fungi, and a study of them is therefore necessary.

As a preliminary, 50 cuttings of chrysanthemum (var. pink Rayonnante) and 50 cuttings of carnation (vars. Northland and William Sim) were planted in tubes of vermiculite and sand respectively. The bases of the cuttings were surface sterilized in bleaching powder solution, the ends cut off and dipped in Seradix before planting. Rooting took place in all the carnation cuttings and in about half the chrysanthemum cuttings. Almost all the chrysanthemum cuttings developed mildew after a short time in the tubes, although none was visible when the cuttings were taken. This suggested that the mildew may grow vegetatively on the shoots and only produce spores under favourable conditions. The chrysanthemum cuttings did not grow well in the tubes owing to heavy contamination with other fungi which it was impossible to control. Seed of various varieties and species of Chrysanthemum was therefore grown in tubes using the same technique as for cucumbers. Seedlings were inoculated with spores of chrysanthemum mildew with the following results:—

Positive infection:—

Large flowered autumn flowering (Sutton's)
Cascade type (Sutton's)
Korean type
Chrysanthemum erubescens

Negative results:—

Chrysanthemum segetum
C. maximum
C. leucanthemum
C. coronarium
C. carinatum

It may be noted that *C. erubescens* is one of the species from which the cultivated varieties are derived. Cucumber mildew was able to infect some of the annual types which were unaffected by the chrysanthemum mildew.

Experiments on carnation cuttings were unsuccessful. The cuttings rooted well and continued healthy, but could not be infected by either cucumber mildew or mildew from carnations in the nursery. It may be that the host conditions were unsuitable.

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3. CARNATION WILT DISEASES

by

MARION H. EBBEN

Wilt diseases of carnations have been reported since early this century, and are now responsible for extensive losses in carnation beds. The development and spread of disease depends on growing methods and on the particular pathogen which is responsible for the disease. In the United Kingdom four different organisms have been recognised as able to cause "Carnation Wilt", *Verticillium cinerescens*, *Fusarium roseum* (sensu Snyder and Hansen), *F. oxysporium* f. *dianthi* and *Erwinia* sp. The appearance of wilt due to any one pathogen depends on the method of primary infection and the type of bed, and on the environmental conditions under which the crop is grown. The method of growing, i.e., in soil or raised beds, influences the spread of the disease from plant to plant, and the environmental conditions, e.g., temperature, affect the spread of the disease organisms within the plant. When wilt appears early in a new carnation crop it is normally due to the use of infected stock plants for cuttings. Later development of wilt may be due to spread through the soil from a few infected plants, or when grown in open soil to the survival of pathogens in organic debris below the level at which steam sterilization is effective.

The occurrence of foot rot and die-back caused by *F. roseum* is rather different from that of the wilts caused by the three other organisms. *Fusarium roseum* is a ubiquitous pathogen and saprophyte, and different strains can attack many species, especially as seedlings or young plants. This fungus is more likely to be present in fresh soil than the more specific carnation pathogens, and frequently is the first cause of wilt in a young crop on fresh or sterilized soil. It was previously considered that *F. roseum* did not cause a true wilt and was a secondary pathogen, but although it is often associated with the other wilt organisms in a secondary capacity it seems frequently to cause wilt without being associated with another pathogen. In France it is reported to be more frequently the cause of wilt than *F. oxysporum* f. *dianthi* (Moreau, 1953). Infection by the other three wilt producing organisms is more likely to come directly or indirectly from previously infected plants, i.e., by the use of infected cuttings or infected soil or beds, or from diseased plant debris. Growing carnations in concrete beds of sterilized or maiden soil decreases the possibility of disease. Wilt organisms in this case may be present in the cuttings when planted out, and aerial infection of broken stems by *Fusarium roseum* can also occur. The growing of cuttings taken from healthy stock is therefore of great importance, and methods of testing cuttings for wilt organisms before striking them in the potting bench are becoming more widely used (Glasscock, 1956, Hellmers, 1955).

Methods of isolating pathogens

Previous workers on carnation wilt diseases have recommended various procedures for isolating the effective pathogen, uncontaminated by secondary organisms. These methods include:—

(1) The use of discoloured stem tissue taken from as high up the plant as possible.

(2) The dissecting out of xylem tissue, the cortical tissue likely to carry secondary organisms being removed under reasonably sterile conditions after surface sterilization.

(3) The use of malic acid agar to prevent bacterial growth.

Isolations made from diseased plants to test these methods suggest that methods (1) and (2) are preferable if contamination by secondary organisms is to be avoided. The use of malic acid agar is less useful and would actually conceal the presence of slow wilt bacteria. For isolating

bacteria, Actidione an anti-fungal antibiotic, has been tested in agar media at a concentration of 0.1 milligrams per millilitre. This was found to inhibit completely the growth of a pure culture of *Verticillium cinerescens*, and greatly retard that of *F. roseum*. In most cases diseased tissue from above the region of any secondary infection can be used for isolating the pathogen, but in some diseased plants the bacteria do not spread very far upwards through the plant and an actidione medium could be used if slow wilt was suspected.

The use of nutrient broth has been found useful for isolating pathogens. Both fungi and bacteria will grow out from surface sterilized stems and isolations of pure cultures can be made on agar plates by streaking. *Fusarium* spp. and slow wilt bacteria can be isolated from infected tissue when incubated in tubes of sterile water, but if symptoms are only slight the use of nutrient broth is preferable.

For surface sterilization mercuric chloride has been found preferable to calcium hypochlorite, although the use of the former necessitates careful washing in sterile water afterwards. Calcium hypochlorite in which chlorine is the active sterilizing agent, does not kill spores of *Chaetomium* spp. This genus includes many soil fungi and often occurs apparently casually and saprophytically on the surface of plants, although a species is known which is reported to be a non-pathogenic endophyte of *Lolium perenne* (McLennan, 1926). The Chaetomia produce a quick growing fluffy mycelium in culture and could easily obscure a slower growing fungus such as *V. cinerescens*, or bacterial growth.

Secondary infection of wilted plants is common especially following a cortical rot of *F. roseum*. Moreau reports several fungi associated with wilt diseases which are not direct pathogens, and bacteria may also invade diseased plant tissue. The results of isolations from diseased plants suggest that although bacterial infection of plants originally parasitised by *Fusarium* spp. or *V. cinerescens* may be unimportant as far as identifying the causal organism is concerned, secondary bacterial infection of plants with slow wilt may be more confusing. On agar plates and in broth the secondary organisms tend to grow faster than *Erwinia* sp., and can only be separated by streaking. Lelliott's method (Lelliott, 1956) of isolating the slow wilt pathogen from xylem vessels teased in water on a sterile slide has also been found useful for Fusaria. Fungal hyphae can sometimes be seen in the vessels and if incubated in sterile water grow quite rapidly, often producing spores. Other secondary fungi can also be tentatively identified using this method.

Inoculation experiments

The slow development of wilt organisms within the plant is one of the difficulties in preventing disease. Cuttings only slightly infected may grow into sizeable plants and be planted out in beds for a year or more before disease symptoms are noticed. If the soil is infected and the cuttings originally disease-free, the plants may be even older before symptoms appear. Since infected plants do not always show symptoms it is possible to take cuttings from an apparently healthy plant which is actually carrying the disease, and mother plants which are only kept for one year may produce cuttings which later develop disease symptoms.

Inoculation experiments suggest that infection of plants through the roots, by soil infection or by standing the plants in fungal or bacterial inoculum produces slow and variable results. Species of *Dianthus* inoculated with fungi by the latter method showed no marked external symptoms after six months, although some internal lesions had developed. No specific disease symptoms had occurred in plants grown from seed in soil infected with *V. cinerescens* and *Fusarium* spp. after several months. Infection through the cut or broken ends of fresh cuttings, however,

seems to produce more rapid, though still variable, symptoms. This method of infection may occur naturally if cuttings are cut from the plant with a contaminated knife or if bundles of cuttings, some of which are infected, are stood together in water before striking.

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4. MUSHROOM DISEASES

by

DOREEN G. GANDY

The study of "La France" disease (2) and similar disorders of mushrooms was continued. The cause of these disorders is not known, but it has been stated by Sinden (private communication) that mycelium taken from a crop with "La France" disease will not grow normally in pure culture. Accordingly, when samples from abnormal crops were received, attempts were made to isolate the mushroom mycelium. They were not all successful, but by the end of 1956 some thirteen cultures had been obtained.

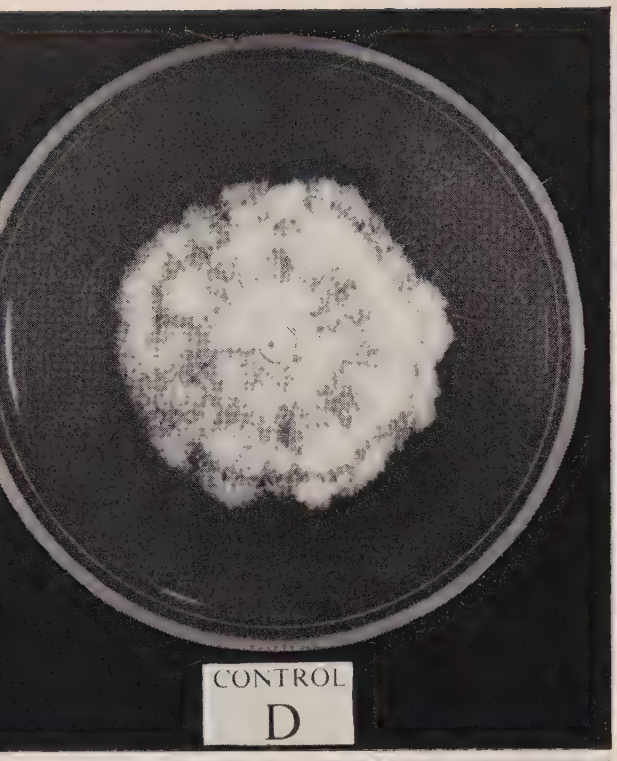
Laboratory experiments

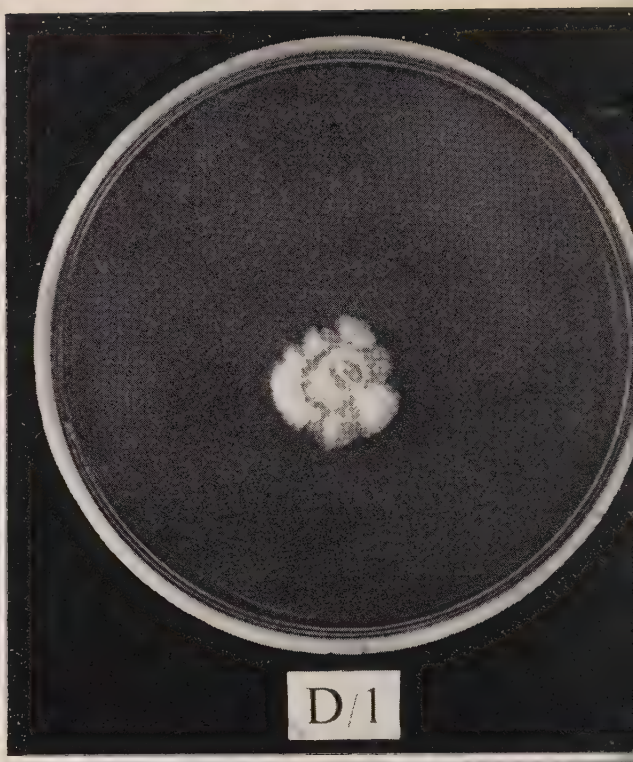
Experiments were set up to compare the growth rates of these cultures with that of normal mushroom mycelium. At the time of the first series of experiments only five cultures were available; they were as follows:

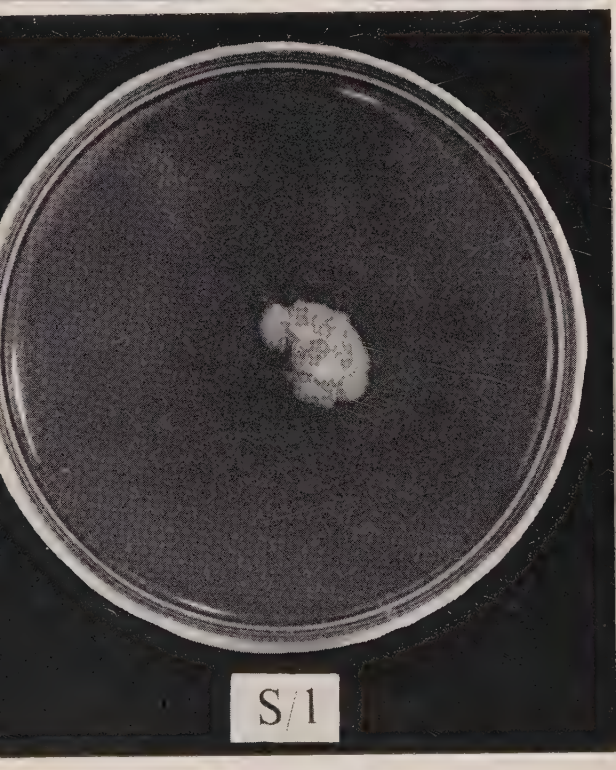
D/1, D/2	From a farm in Kent. A yield of ¾lb./sq.ft. of mushrooms had been produced in nine weeks and the house was about to be emptied.
D/3	From another house on the same farm. The previous crop in this house had been affected and no special measures had been taken to disinfect the house between crops apart from routine spraying. The culture was isolated from a sample taken fourteen days after spawning, before any abnormal condition could be seen.
S/1	From a farm in West Sussex. Mushrooms had long stipes and cropping was below normal.
T/1	From another farm in West Sussex. Mushrooms were dying and rotting before reaching maturity.

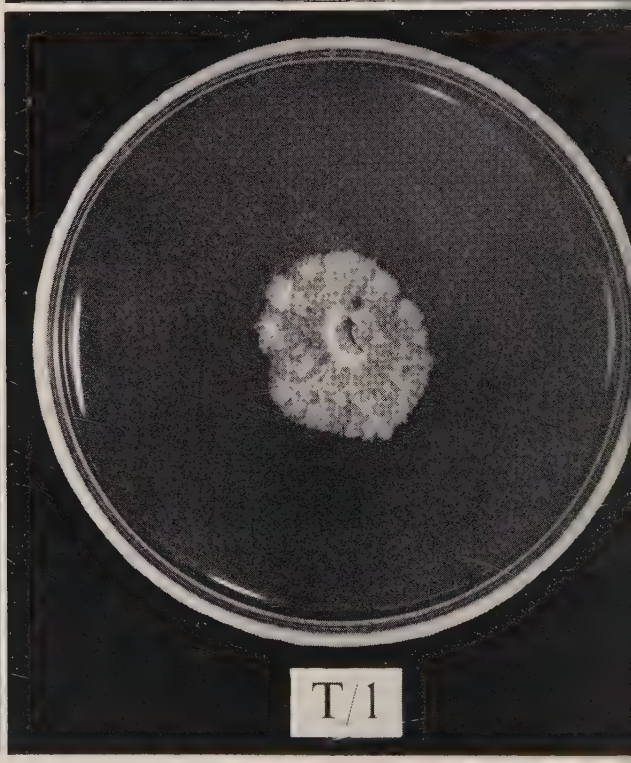
For comparison, five normal cultures, numbered (1) to (5), were isolated, in each case from a commercially prepared spawn.

Plates of 2½% malt agar were inoculated with discs of mycelium 6 mm. in diameter, cut from stock plates, and incubated at 25°C. The diameter at right angles of each colony was measured three times a week. The earlier experiments were spoilt by considerable contamination of the plates. Table I shows the mean diameter of the colonies at three weeks in an experiment where there was no contamination.









Mushroom colonies two weeks after inoculation
Note differences in rates of growth and appearance of the mycelium

To face page

TABLE I

Mean diameter of colonies three weeks after inoculation

Culture ..	(1)	(2)	(3)	(4)	(5)	D/1	D/2	D/3	S/1	T/1
Diam. (mm.)	57	58	41	62	58	43	21	59	22	43

The difference in growth rate between spawn (3) and the other four spawns was significant so it could not be regarded as a reliable control. There was a significant difference (1%-level) between the growth rates of the other four controls and those of D/1, D/2, S/1 and T/1; but not of D/3. It is of interest to note that the spawn from which D/3 was obtained produced a crop totalling 2 lb./sq.ft in $6\frac{1}{2}$ weeks.

Similar experiments were carried out again when more cultures became available. These were:

M/1 — From Yorkshire. Considerable browning and dying off of mushrooms occurring in many houses.

R/1, R/2 — From Salop. Mushrooms were producing very long stipes and the cropping had been poor for some months. The symptoms did not appear to be typical of the "La France" type of disorder.

P/1 — From West Sussex. The crop was a complete failure. Eelworms and Cecids were present. The mycelium appeared to be dying in many places where these pests were apparently absent.

L/1 — From Worcestershire. A disorder claimed to be "La France" had been present on the farm for many months.

L/1 tissue — A tissue culture from an abnormal mushroom grown on the above farm.

G/1, G/2 — From Somerset. The symptoms were similar to those described for "La France." Phorid flies were also numerous on the farm.

(1) — Control.

The mean diameters of the colonies three weeks after inoculation are shown in Table II.

TABLE II

Mean diameters of colonies three weeks after inoculation

Culture ..	(1)	M/1	R/1	R/2	P/1	L/1	L/lt.	G/1	G/2	S/1	T/1
Diam. (mm.)	64	36	53	53	50	50	45	25	29	31	47

It appears from the results so far obtained that mycelium isolated from crops with "La France" or a similar disorder, even when able to grow in pure culture, may exhibit an abnormally slow growth rate.

Other abnormal characters also noted are:

(i) Colour: frequently pale buff instead of white.

(ii) The poor development or complete absence of coarse mycelial strands radiating from the point of inoculation.

A study of the microscopic characters of these cultures has been started.

Experiments in the mushroom house

Since the symptoms observed on mushroom farms may be due in part to environmental conditions it was considered desirable to compare the behaviour of these cultures under the same growing conditions in a mushroom house. Spawn was prepared as follows:

> Glass jars were filled with washed mushroom compost, plugged with cotton wool and autoclaved at 20 lb. pressure for two hours. After cooling they were inoculated and incubated at 25°C. until the mycelium had permeated the compost.

Again it was noticed that the growth of D/1, D/2 and T/1 was much slower than that of the control spawns or D/3.

For this experiment spawns (1), (2) and (3) were used as controls. Spawn of S/1 could not be prepared in time so it had to be omitted.

One-hundred-and-five 10in. concrete pots, lined with plastic sheeting to reduce porosity, were filled with compost made according to the M.R.A. formula. They were peak heated and spawned. Casing was carried out twenty-six days after spawning. Since the casing may have some effect on the appearance of the disorders observed, three types were used:

(*a*) Sphagnum peat mixed with an equal volume of lump chalk.

(*b*) Local subsoil, steam sterilized, plus calcium carbonate to adjust the *p*H.

(*c*) Horticultural vermiculite.

After casing the pots were treated in accordance with normal commercial practice. The yield of mushrooms in a ten-week period following the date of the first pick on each pot was recorded (see Table III).

TABLE III

First pot experiment. Yield of mushrooms after ten weeks.

SPAWN	(1)		(2)		(3)		D/1		D/2		D/3		T/1	
	No.	Wt. (*g.*)	No.	Wt. (*g.*)	No.	Wt. (*g.*)	No.	Wt. (*g.*)	No.	Wt. (*g.*)	No.	Wt. (*g.*)	No.	Wt. (*g.*)
Casing														
Peat	97	887	34	130	61	879	—	—	32	181	109	951	65	282
Soil	84	728	63	549	75	880	—	—	39	173	87	778	42	167
Vermiculite ..	106	928	73	834	70	905	5	47	50	269	107	888	33	114
TOTAL YIELD	287	2,543	170	1,513	206	2,664	5	47	121	623	303	2,617	140	563
No. of pots which cropped (out of 15)	15		10		15		1		15		15		15	
Mean yield per pot	19	170	17	151	14	178	5	47	8	42	20	175	9	38

The yield of D/1, and to a lesser extent (2), was unsatisfactory. Each culture was grown in fifteen pots, but only one pot of D/1 and ten of (2) produced mushrooms. When the non-yielding pots were examined, it was found that the compost had become very wet and that the mushroom mycelium had died. Owing to the dry conditions in the mushroom house frequent watering had been necessary, thus increasing the danger of over-watering. The more vigorous cultures were able to withstand such treatment but the weaker ones succumbed. The actual cropping period for each pot is shown in Figure 1. It will be seen that many of them did not crop for the full ten weeks.

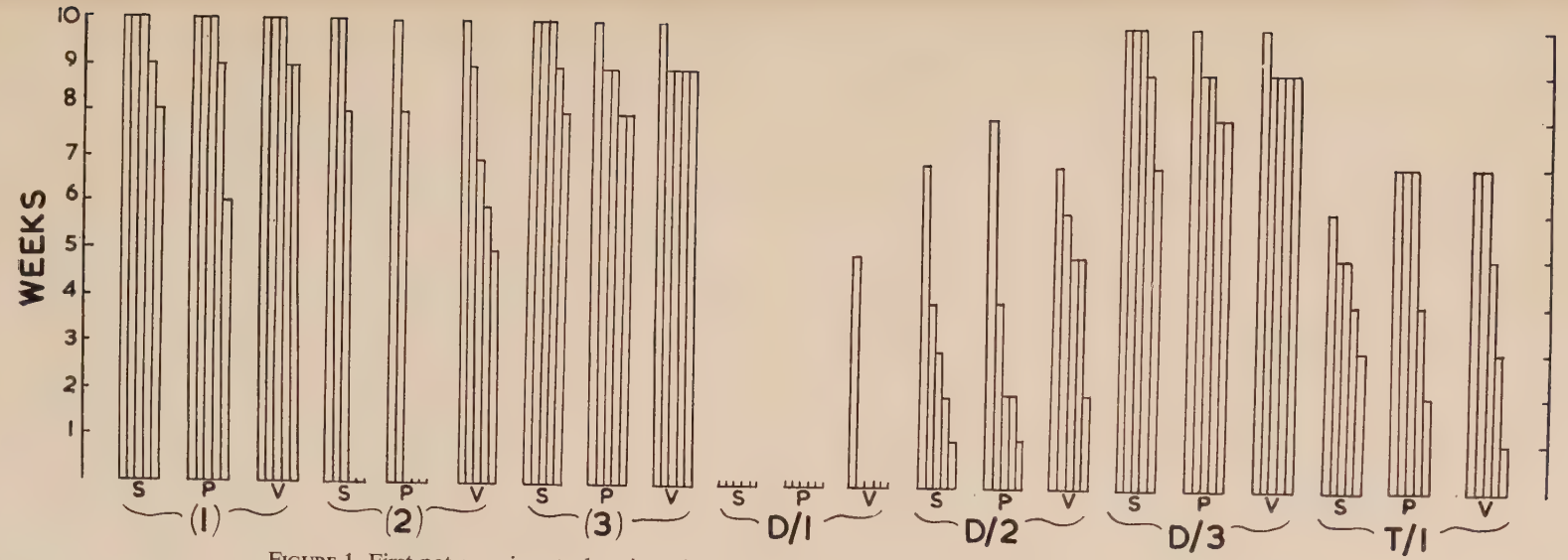


FIGURE 1. First pot experiment; duration of cropping. (S—soil casing, P—peat casing, V—vermiculite casing)

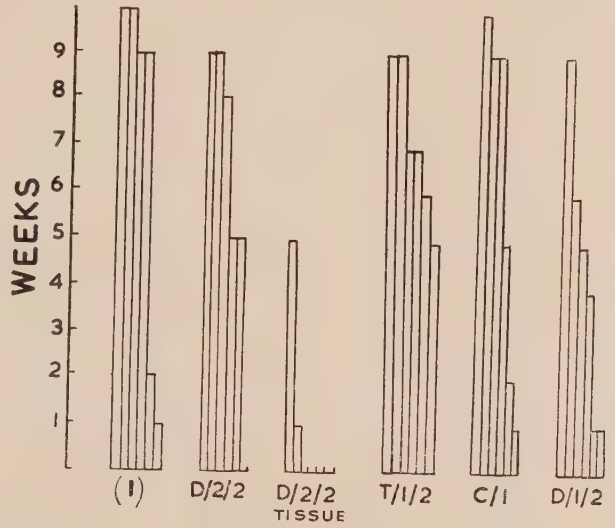


FIGURE 2. Second pot experiment; duration of cropping

There was a significant difference in yield between the control spawns and D/1, D/2 and T/1, but not from the different casings.

The sporophores produced by D/2 and T/1 during the first month of cropping were normal, but after this period they became smaller and had longer stipes. This was the only sporophore abnormality observed throughout the experiment.

A second experiment was carried out on similar lines using the following spawns:

(1)	Control.
D/1/2	Re-isolated from D/1 from the previous experiment.
D/2/2	Re-isolated from D/2 from the previous experiment.
D/2/2 tissue	A tissue culture from a sporophore produced by D/2.
T/1/2	Re-isolated from T/1
S/1	As used in the growth rate experiments.
C/1	From Devon. From a description of the disorder sent in by the N.A.A.S. it appeared unlikely to fall into the category of disorders being studied.

One casing material was used, steam-sterilized subsoil.

The yields are shown in Table IV.

TABLE IV

Second pot experiment. Yield of mushrooms after ten weeks.

SPAWN	(1)		D/1/2		D/2/2		D/2/2 tissue		T/1/2		S/1		C/1	
	No.	Wt. (g.)	No.	Wt. (g.)	No.	Wt. (g.)	No.	Wt. (g.)	No.	Wt. (g.)	No.	Wt. (g.)	No.	Wt. (g.)
	87	1,246	28	543	55	1,023	7	118	126	997	14	114	104	1,576
No. of pots which cropped (out of 6)	6		6		6		2		6		3		6	
Mean yield per pot	15	208	5	91	9	171	4	59	21	166	5	38	17.3	263

Although a greater proportion of pots cropped in this experiment, the results were still not satisfactory because many of the pots did not crop for the full ten weeks (see Figure 2). The correct watering of the pots remained a serious problem, due to the high temperature and low relative humidity of the atmosphere in the house. In the period October 15th to December 3rd, 1956, during which most of the mushrooms were picked, the mean temperature was 69.5°F. which is rather high, and the mean R.H. was 70%, but during this period of 1,180 hours the R.H. was below 60% for 178 hours and above 80% for only 124 hours. On several occasions the pots had to be watered twice in one day. As in the previous experiment, the mycelium died out in several pots. In others it remained alive, but cropping ceased prematurely. Pots appear to be too susceptible to fluctuations in temperature and humidity to be suitable for the study of mushroom strains which are not vigorous, and it is hoped to use larger units in future experiments.

Size and form in mushrooms

In collaboration with P. B. Flegg, of the Chemistry Department, a study was made of size and form in normal and abnormal mushroom sporophores. The results were presented at the Third International Conference on Mushroom Science, Paris (1).

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VI. ENTOMOLOGY

1. INTRODUCTION

The year was essentially one of transition occasioned by the appointment of a new Head of Department and the transference of Miss B. Gurney to the staff. The studies on the effects of temperature on the developmental cycle of *Tetranychus telarius* L, were continued, but the realisation that more than one species was involved in the present conception of *T. telarius* prompted the initiation of cross-breeding experiments between the colour forms (1955 Report). This work is still in progress.

Work has also begun on studies on the effect of temperature on the development of the White-flies *Trialeurodes vaporariorum* Westw. and *T. sonchi* Kot. to provide basic data for future work on the effects of the physical environment on population balance between these whiteflies and their parasites.

The department has also undertaken active research in the field of mushroom pests where much essential biological information is lacking. This initial work has been hampered by the lack of suitable facilities in the form of beds from which large samples of compost could be examined regularly. The studies have therefore been limited to light-trap work and faunal sampling of materials used in the formation of mushroom beds to familiarise our workers with the insects normally associated with such materials.

2. MUSHROOM INSECTS

by

N. W. HUSSEY

Fauna of light racing stable manure

This material, which is in fact only soiled straw, was collected fresh once a month from a local stables before it had been piled. Two buckets of the manure were placed on rough grass along the boundary hedge of the Institute. Samples (in 1-lb. jars) were taken at 1, 2 and 3 day, 1, 2, 3 and 4 week intervals.

With the object of confirming the conclusions of Austin and Jary (1934, 1935) all the emergent adult insects, excepting Collembola, were determined. For this purpose each sample was maintained in the laboratory for 82 days. It is intended that the study should extend over twelve months, and in the first six months, reported in Table I, 64 species have already been bred out.

TABLE I

Fauna of racing stable manure exposed for monthly periods from indicated dates

	27/6/56	25/7/56	22/8/56	19/9/56	17/10/56	13/11/56
DIPTERA						
Sphaeroceridae						
Alloborborus flavipennis (Hal.)				1		
Coprophila ferruginata (Stenh.)	9	3		2		
C. vagans (Hal.)	13	37	2	3		
C. pseudolugubris Duda	11	98	20	6		
Halidayina spinipennis (Hal.)	11	12	2			
Leptocera clunipes (Mg.)	15	13	35	8	293	26
L. coprina Duda				12	16	
Limosina heteroneura Hal.	24	403	26	26		
L. palmata Richards	14	25		89	2	
L. silvatica (Mg.)			3	54		
Sphaerocera curvipes Latr.	35	6	44	10	23	
S. parapusilla Duda	2					
S. pusilla (Fall.)	130	113	9	4	12	
S. monilis Hal.			2	2		
Trichiaspis equina (Fall.)				3	179	579
Muscidae						
Azelia macquarti (Stacq.)						1
Dendrophaonia querceti (Bouché)	1	9				
Fannia canicularis (L.)	2		2			
Hydrotaea similis Meade		2				
Phaonia variegata (Mg.)						2
Stomoxys calcitrans (L.)	7	2			1	
Scatopsidae						
Swammerdamella brevicornis (Mg.)		1				
Tipulidae						
Rhipidia maculata Mg.		78	157	73	22	
Cordiluridae						
Scopeuma stercorarium (L.)					5	
Stratiomyidae						
Microchrysa flavicornis (Mg.)	11		1	1		
Sciaridae						
Sciara auripila Winn		9	7		59	12
S. fenestralis Zett			54		12	
S. modesta Staeger					67	484
S. umbratica Zett	175	1		14	65	
Sciarid sp. "F"	20					24
Sepsidae	1	1				
Empidae	1	3				
Psychodidae	17	156	313	421	304	30
Chironomidae	106	126	32	38	17	16
Cecidomyiidae						
Cecidomyiini	19	18	75	16	4	5
Lestremiinae			8	4	20	

TABLE I—*contd.*

Fauna of racing stable manure exposed for monthly periods from indicated dates

	27/6/56	25/7/56	22/8/56	19/9/56	17/10/56	13/11/56
COLEOPTERA						
Anotylus tetracarinatus (Block) ..		17	5	1		
A. inustus Gravenhorst	5				1	
A. sculpturatus Grav.					1	
Oxytelus laqueatus (Marsh.)					1	
Autalia rivularis (Grav.)	1	5	2			
Atomaria nigriventris Steph.	8	1	1			
Omalium rugatum Rey.					1	
O. rivulare (Payk.)					1	2
Acrolocha sulcula (Steph.)				2		
Chaetida longicornis (Grav.)	1					
Pseudophonus pubescens (Payk.) ..		1				
Cryptopleurum minutum (F.)		1				
Micraspis sexdecimpunctata (L.) ..		1				
Stilbus testaceus (Panz.)		1				
Megarthrus denticollis (Beck)		1				
Philonthus nigriventris Thoms. ..			1			
Tachinus rufipes (De G.)				1		
Aphodius fimetarius (L.)						1
Aphodius obliteratus Panz.					1	
Acrotrichis grandicollis (Mann.) ..		1	5	5		
Megasternum obscurum (Marsh.) ..		2	11	14	1	
Sphaeridium bipustulatum F. ..		1				
Cercyon analis (Payk.)		1				
C. depressus Steph.	2		1			
C. haemorrhoidalis (F.)	2	1	3	5		
C. lateralis (Marsh.)			2	1	1	
C. melanocephalus (L.)	4	6	2		4	1
C. minutus L.	1					
C. pygmaeus (Ill.)	1	1	1	5		
C. terminatus (Marsh.)		1				
C. unipunctatus (L.)			2		1	
C. lugubris (Olivier)			2			
Micropeplus staphylinoides (Marsh.) ..				1		

Fauna of artificial compost.

On July 2nd, wheat straw was stacked and watered with the addition of M.R.A. activators to prepare compost for the mushroom house filled on August 1st. Samples (1-lb.) of this material were collected before each turn of the compost and on the day before the beds were filled.

The species bred from these samples are recorded in Table II. In general the insect population of this artificial compost was low, e.g., 46 insects/lb. of compost compared with 128/lb. of stable manure.

Infection of this compost by *Sciara fenestralis* is important from a practical point of view, bearing in mind its known habits as a mushroom pest. These Sciarids and the two Sphaerocerids which emerged from the last sample had survived despite the fact that the temperature inside the compost stack reached 160°F.

TABLE II

Species bred from 1 lb. samples of wheat straw during composting

Before 1st turn (9/7/56)	Before 2nd turn (16/7/56)	Before 3rd turn (23/7/56)	Before bedding (30/7/56)
Coprophila pseudolugubris 1	Coprophila ferruginata .. 7	Coprophila ferruginata .. 3	Coprophila ferruginata .. 2
Limosina palmata 2	Leptocera clunipes 2	C. pseudolugubris 14	Sciara fenestralis 121
Sphaerocera pusilla 4	Sphaerocera pusilla 1	Leptocera clunipes 9	Stomoxys calcitrans .. 1
Bolitobius exoletus Er. .. 1		Sphaerocera pusilla 13	
		Stomoxys calcitrans .. 2	
		Cercyon melanocephalus .. 3	

Further samples of this artificial compost were used to compare the faunas of spawned and unspawned compost. Eight samples were spawned with commercial spawn and kept at 75°F. for a fortnight to allow the mycelium to permeate the sample. These, together with four unspawned samples, were placed in the grassland surrounding the Institute. The insects bred out from these samples, exposed for 5–40 days, are listed in Table III.

TABLE III

Species bred from compost, spawned and unspawned, exposed in the open

Species	Spawned	Unspawned
Sciara auripila	169	—
S. fenestralis	114	106
S. vivida	14	—
Megaselia halterata	59	—
Coprophila ferruginata	—	12
Leptocera clunipes	15	4
Limosina heteroneura	15	18
Sphaerocera monilis	1	—
S. pusilla	1	—
Halidayina spinipennis	2	—
Microchrysa flavicornis	1	—
Cecidomyidae	5	—
Aldrovandiella coxendix Ver. ..	1	—

It is important to notice that the Phorid *Megaselia* is restricted to the spawned material.

Light trap records

A light-trap using a 40-watt. bulb and baffles to direct the attracted insects into a vessel containing 50% alcohol was constructed so that catches could be examined at weekly intervals without deterioration of the smaller species.

The house was filled on August 1st, peak-heating reached 120°F. in both air and beds and continued until August 7th. The beds were spawned on August 10th and the first pin-heads were observed on September 21st. Cropping ceased on December 12th.

The catches are analysed in Table IV. Identifications to species were confined to those groups known to contain mushroom pests, but in the case of the Sciaridae it is only possible, in the present state of knowledge, to determine males. This has made interpretation of the large catches difficult especially as the ratio female: male rose from about 6:1 in the period up to October 22nd to about 100:1 or even infinity from then until cessation of trapping. However, all the species recorded have been cited as mushroom pests by Austin and Pitcher (1936) except *S. modesta* which is a general pest in all the glasshouses at the Institute.

We are indebted to Mr. C. N. Collyer for confirmation of our determinations of Phoridae and it will be noticed that the catches were almost exclusively *Megaselia halterata*, better known as the Worthing Phorid Fly.

It is not possible to reach definite conclusions regarding the peaks observed as the numbers of flies entering the house through the ventilators could not be distinguished from those emerging from the beds.

TABLE IV

Insect species caught in mushroom house light trap

	8/8/56	13/8/56	20/8/56	27/8/56	3/9/56	10/9/56	17/9/56	24/9/56	1/10/56	8/10/56	15/10/56	22/10/56	29/10/56	5/11/56	12/11/56	19/11/56	26/11/56	3/12/56	10/12/56	17/12/56
Sciara auripila			4	3			2													4
S. fenestralis										1	1	1					2			
S. agraria																	1			5
S. modesta					5		6	4	1		4			1						
S. vivida		2					1													5
Sciara sp. unidentified ♀		12	14	17	5	10	17	18	18	9	8	8	22	34	46	63	691	316	167	315
Sciara sp. unidentified ♂			2							1										1
Megaselia halterata (Wood)	1	8	6	61	153	73	259	331	389	66	64	59	179	105	120	66	784	270	123	88
M. nigra (Mg)		1								8	24	6	2	2		3				
M. pleuralis (Wood) ..		1	1							1			1		1			1		
Coprophila ferruginata ..	2	1																		
C. pseudolugubris.. ..	8	9	3	1																
Leptocera clunipes ..						1	2		4	1			7	2						
Limosina heteroneura ..				3	1	26	7	2	3	16	3			4		4				
L. palmata		1	4												8					
Paracollinella fontinalis ..	2																			
Cercyon depressus ..	1																			
C. melanocephalus ..		1																		
Scatopse fuscipes Mg. ..						109	63	23	17	30	41	168	255	372	221	172	327	130	272	121
Cecidomyiinae		5	6	14	2	3	4	4	4	2		1	1		10					
Heteropeza sp.															10	10	113	35	57	77
Coleoptera undetermined	1	6	1	8	3	9	10	1	4	8	15	2	5		3	4	5		2	1
Diptera .. ,, ..	2		7	7	5	1		12	5	2				1	1		1			
Hymenoptera ,, ..		7	3	14	1	2	1	4	1	1					1					
Lepidoptera ,, ..	1		1			1	1			1	1									
Hemiptera ,, ..		1	3	3		3	2										1		1	
Chironomidae			7	11	6	1	38	13	3	3	2		2		1		2			1
Psychodidae		3	2	8	2	6	11			3	3	6	4	1			2		1	1
Sphaerocera pusilla ..	2	1		1		1														
Acrotrichus grandicollis ..											13	36	39	30	17	16	30	14	22	34

The most unusual feature of the results was the large number of Scatopsids trapped. The most common species was *Scatopse fuscipes*, but a few *S. flavicollis* Mg. and *S. picea* Mg. were included in the last collection. The natural habitat of these species is not clear from the literature but Guyer *et al.* (1956) record *S. fuscipes* from grass silage in Michigan.

The Cecidomyiidae are of especial interest in view of the importance of the paedogenetic forms in mushroom culture. All the Cecids recorded were *Cecidomyiinae* except three unidentified *Lestremiines* captured on October 8th, 22nd and 29th. The relatively large numbers of *Heteropeza* adults trapped after November 12th (or eight weeks after the first flush) is a valuable observation for future live trapping of this undescribed species.

A contributing factor to the irregular population fluctuations was the use of insecticides applied during normal hygiene operations. When these insecticides were applied special observations of the trap contents were made immediately before and two days after the applications.

In the case of dust applications of D.D.T. 1% on September 14th and BHC 5% on September 21st, no reduction in the trapping rate took place. But diazinon aerosols (3 fl. oz./8,000 cu. ft.) caused a significant reduction in the trapping rate for all the important groups (Table V).

TABLE V

% Reduction in the trapping rate per hour following application of diazinon

	Date of application	
	26/9/56	29/11/56
Sciaridae	74	93
Scatopsidae	90	67
Phoridae	86	95
Heteropeza sp. ..	—	83

It is vital to secure data on the rate of adult emergence from the beds if light trap records are to be interpreted correctly, and it is hoped to obtain this information during 1957.

Conclusions

It is premature to draw conclusions from the faunal studies until they have continued for a full calendar year, but certain trends seem evident. Phorids are obviously only attracted to material in which mushroom mycelium is present and hence only infest mushroom houses after spawning—contrary to the opinions of Thomas (1942). The Sciarids, especially *S. auripila*, *S. fenestralis* and *S. umbratica*, are attracted to manure heaps and may therefore enter the houses with the compost. *S. vivida* may be mycophilous and only enter houses after spawning.

Evidence on Cecids is still scanty but as none of the paedogenetic *Lestremiines* bred from stable manure were caught in numbers by the light trap inside the mushroom house it would seem that only *Heteropeza* is of economic importance there. The mode of infection by this species remains unknown.

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3. RED SPIDER MITE (*TETRANYCHUS TELARIUS* L.)

by

W. J. PARR

In view of the economic importance of this pest on glasshouse crops it is desirable that the effect of environment on its rate of development be accurately determined in order that the intervals between acaricide applications can be estimated more effectively. The only available figures are those of Van Marle (3) and Linke (2) and these are either based on a few scattered observations or cover an outdoor temperature range too low to be applicable to glasshouse conditions.

Experiments were therefore set up to determine the effect of temperature on the rate of development of eggs and young mites under conditions both of long day-length and total darkness.

To obtain uniformity, an initial stock of the red form of *T. telarius*, now considered by some workers to be *T. cinnabarinus* Bois (1), was started by inbreeding from a single female taken from arum. Subsequently, the stock was maintained upon French bean.

Females in the deutonymph resting stage were each isolated on discs cut from leaves of French bean and floated on nutrient solution. One or two males were placed in company with each female to ensure the production of fertile eggs. Some of the discs were kept in glass-fronted incubators and given 16 hours illumination daily from a mercury vapour lamp, others were kept in similar incubators with the outer door closed so that the mites developed in total darkness. The temperature of the incubators could be controlled within ± 1.0°F., and the intensity of light falling on the discs from the mercury vapour lamp was estimated at 400 f.c.

The discs were examined three times daily and only those eggs laid within the previous four hour period were used for development data. They were marked with coloured paper pointers and kept under frequent observation in order to determine as accurately as possible the period of incubation. The results are shown in Table I.

TABLE I

Incubation period of the eggs of *Tetranychus telarius* in days

Temp. (°F.) (±1.0°)	16 hrs. Photoperiod			Total darkness		
	No. in sample	Mean	Range	No. in sample	Mean	Range
70	46	5.9	5.5 — 6.5	28	6.4	5.8 — 7.0
75	47	4.6	4.3 — 5.0	25	4.3	4.1 — 4.5
80	45	3.6	3.1 — 3.9	30	3.3	3.0 — 4.1
85	45	2.9	2.8 — 3.1	33	2.8	2.7 — 3.0
90	36	2.7	2.5 — 2.9	25	2.7	2.6 — 2.8
95	45	2.3	2.2 — 2.7	41	2.5	2.2 — 3.0

Considerable numbers of the larvae obtained were kept singly on floating bean discs in the incubators in which the eggs had hatched. Only those which had emerged not more than three hours previously were used; they were transferred to fresh discs periodically during their development. At all temperatures, and in the presence or absence of light, a fairly high proportion of young mites reached maturity.

Details of the results for those mites receiving a daily photo-period of 16 hours are set out in Table II.

TABLE II

Period of development (in days) of *Tetranychus telarius* at constant temperatures and 16 hours photoperiod

Temp. (°F.) (±1.0°)	Number and Sex	Larva				Protonymph				Deutonymph				TOTAL	
		Active		Quiescent		Active		Quiescent		Active		Quiescent			
		Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
70	18 Females	1.3	1.0 — 1.5	1.2	1.0 — 1.7	0.9	0.7 — 1.2	1.2	1.0 — 1.3	1.1	0.9 — 1.2	1.7	1.4 — 1.9	7.4	7.0 — 8.0
	8 Males	1.0	0.9 — 1.3	1.2	1.1 — 1.2	0.7	0.6 — 0.9	1.2	1.0 — 1.4	0.9	0.8 — 1.0	1.8	1.5 — 1.9	6.8	6.6 — 7.1
75	14 Females	1.0	0.8 — 1.3	0.9	0.8 — 0.9	0.7	0.7 — 0.8	0.9	0.7 — 1.0	0.9	0.8 — 1.2	1.3	1.0 — 1.6	5.7	5.4 — 6.1
	11 Males	0.9	0.8 — 1.0	0.8	0.7 — 1.0	0.7	0.6 — 0.8	0.7	0.6 — 0.9	0.7	0.6 — 0.7	1.1	0.9 — 1.2	4.9	4.6 — 5.1
80	14 Females	0.7	0.7 — 1.1	0.7	0.7 — 0.8	0.6	0.5 — 0.7	0.7	0.5 — 0.7	0.7	0.4 — 0.8	1.0	0.8 — 1.1	4.4	4.1 — 5.0
	9 Males	0.7	0.6 — 0.8	0.7	0.5 — 0.8	0.6	0.5 — 0.7	0.6	0.4 — 0.7	0.5	0.4 — 0.6	0.9	0.8 — 1.0	4.0	3.8 — 4.0
85	10 Females	0.6	0.6 — 0.8	0.6	0.5 — 0.6	0.5	0.4 — 0.6	0.5	0.5 — 0.6	0.6	0.5 — 0.6	0.8	0.7 — 0.9	3.6	3.3 — 3.7
	7 Males	0.6	0.5 — 0.6	0.5	0.4 — 0.6	0.4	0.4 — 0.6	0.5	0.4 — 0.5	0.4	0.4 — 0.5	0.6	0.5 — 0.6	3.0	2.8 — 3.1
90	9 Females	0.6	0.5 — 0.6	0.5	0.5 — 0.7	0.5	0.4 — 0.5	0.5	0.5 — 0.6	0.5	0.5 — 0.6	0.8	0.7 — 0.9	3.4	3.3 — 3.5
	10 Males	0.5	—	0.4	0.4 — 0.5	0.4	0.3 — 0.4	0.4	0.4 — 0.5	0.5	0.4 — 0.6	0.6	0.5 — 0.6	2.8	2.7 — 3.1
95	13 Females	0.6	0.5 — 0.8	0.6	0.4 — 0.8	0.5	0.4 — 0.8	0.7	0.4 — 0.9	0.8	0.6 — 1.1	0.9	0.7 — 1.2	4.1	3.1 — 4.8
	5 Males	0.6	0.5 — 0.6	0.4	0.4 — 0.5	0.5	0.3 — 0.5	0.5	0.4 — 0.7	0.7	0.6 — 0.8	0.8	0.8 — 1.1	3.5	3.1 — 3.8

Those which completed their development in total darkness gave closely comparable results, but for each temperature the total development period of both sexes was prolonged by about 12 hours. This difference, though small, was nevertheless found to be significant at the 5% level.

At 95°F., the discs, both in the light and dark, deteriorated rapidly and necessitated frequent transfer of the young mites to fresh discs. These repeated changes affected the mites adversely and were no doubt responsible for the apparent retardation in their development at this temperature.

From these data it became apparent that a definite relationship exists between temperature and rate of development. The rate at which both the eggs and young mites developed was accelerated by approximately 22% for each 5°F. rise in temperature within the range 70°—85°F. Above 85°F. the period of incubation of the eggs was still further reduced, whereas no corresponding reduction in the period of development of the young mites occurred. It seems likely, therefore, that the peak rate of post-embryonal development was reached at this temperature. The range of variation in the duration of development among individuals of both sexes kept at the same temperature was remarkably small.

This work is being extended into the lower temperature ranges and special attention is to be given to the effects of the considerable diurnal temperature range experienced in glasshouses.

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VII. CROP PROTECTION

by

W. H. READ, J. T. HUGHES, R. J. SMITH, VALERIE GENTLE

Acaricides

Investigations on the control of red spider (*Tetranychus telarius* L.) on cucumbers have been continued and a number of new compounds have been examined. Certain of these compounds were similar in structure to fenson and other persistent acaricides which are widely and successfully used on a number of tolerant plants. Of these, 1:1–bis(*p*-chlorophenyl) 2:2:2-trichloroethanol, the active material in Kelthane, was the most promising but was too phytotoxic to young cucumbers at .025%. Inconsistent results were obtained with 2:4:5:4'—tetrachloro-diphenyl sulphone which proved somewhat phytotoxic to young cucumbers at 0.4%, at which concentration the control of red spider was unsatisfactory.

Of the non-persistent acaricides, diazinon (diethyl 6-methyl-2-*iso*propyl-4-pyrimidinyl phosphorothionate) showed considerable merit. Trials in the cucumber houses at the Institute showed that when applied as an aerosol at 2.0 g./1000 cubic feet practically complete control of active stages of the mite were obtained.

Preliminary trials with a preparation (now termed Tetram) containing the hydrogen oxalate salt of diethyl S-2-diethylaminoethyl phosphorothiolate showed that this compound is a very potent systemic acaricide. Red spider Mites on carnation plants (about nine months from cuttings) were killled by the application of a solution containing 100 p.p.m. to the soil (25 ml. per 6 in. pot) or by spraying with a solution containing 40 p.p.m., and the foliage remained toxic to the mites for at least six weeks where the chemical was applied to the soil. In view of the high mammalian toxicity of this compound the hazards which might arise from its use on ornamental glasshouse plants must be investigated before recommendations concerning its use can be made.

Fungicides

Didymella Stem-Rot of Tomatoes

During the year ethyl mercury phosphate was withheld from the horticultural market pending decisions as to the safety to workers of the use of this compound for treating the soil in glasshouses to prevent Stem-Rot by *Didymella*, and no equally effective treatment could be substituted. This fact, and also the absence of any reliable non-hazardous fungicide for the control of lesions on stems, have led to a return to the investigation of soil treatments for the prevention of *Didymella*.

Twenty non-mercurial fungicides, including recently introduced proprietary commercial products and compounds synthesised in the laboratory, found highly fungicidal in laboratory tests to spores of *Didymella lycopersici*, have been tested in the following manner. The stems of tomato plants growing in 6 in. pots were wounded at, or just above, soil level by scraping in three places. The pots were then filled with a layer of about one and a half inches of a thoroughly mixed compost consisting of sterilised soil (20 parts) and a sand/oatmeal culture of *D. lycopersici* (1 part). Two hundred ml. of an aqueous suspension containing the required concentration (usually 0.2%—0.05%) of the test compound were immediately applied evenly to the soil surface of each pot and to the lower part of the stem of the plant. Where necessary 0.05% of methyl ethyl cellulose ('Cellofas A') was present as a dispersing and wetting agent. The pots were not watered again for at least twenty-four hours. After a week the stems were again wounded in three places below soil level by scraping with a sharp, sterilised scalpel. The control plants were given the same treatment except that 200 ml. of a 0.05% solution of 'Cellofas A' were applied instead of a suspension of a fungicide. The plants, other than those showing obvious signs of *Didymella* earlier, were grown on for three months after treatment with the test compounds and then the stems of apparently healthy plants were examined for *Didymella* lesions.

The results of these tests were somewhat variable and no compound of definite promise was found. The full results, together with those obtained in earlier work, will be published later.

Further tests with griseofulvin, both as a soil treatment and as a foliar spray, have been made. The application of this compound at 0.1 g. and 0.05 g. per six inch pot in the above test method failed to control the disease. In another test five tomato plants, thoroughly sprayed with a 0.1% suspension of griseofulvin (formulated as a wettable powder) on June 5th, 13th, 21st and 29th and on July 9th and 17th, were inoculated with spores of *D. lycopersici* on June 24th. The treated plants proved as susceptible to attack by the disease as the control plants.

Tomato Leaf-Mould (*Cladosporium fulvum*) *and Cucumber Mildew* (*Erysiphe cichoracearum*)

Tests to evaluate the eradicative and protective value of compounds against Tomato Leaf-Mould and Cucumber Mildew have been continued, mainly with compounds synthesised in the laboratory. One of these new compounds appeared to be very effective for the control of these diseases in preliminary tests in 1956. Further work on this compound, together with the preparation and evaluation of additional compounds of this series, will be carried out in 1957.

Investigations on residues of Acaricides

Colorimetric methods

The published methods for chlorobenzilate (ethyl *p.p.*'-dichlorobenzilate), chlorbenside (*p*-chlorobenzyl *p*-chlorophenyl sulphide) and chlorfenson (*p*-chlorophenyl *p*-chlorobenzenesulphonate or 'ovotran') have been investigated. The method for the determination of chlorfenson is applicable for the determination of fenson (*p*-chlorophenyl benzenesulphonate).

By the adoption of a micro-steam-distillation method for the isolation of the *p*-chlorophenol and standardising the conditions of this distillation the sensitivity of the method has been greatly increased. Modification of the conditions for the colorimetric determination of the *p*-chlorophenol have also been found advantageous. Only limited success has been obtained from attempts to differentiate with sufficient accuracy between superficial foliage deposits and residual material which has penetrated leaf tissue and so obtain information on the relative rates of penetration of different acaricides. High solvent (benzene) blanks and the presence of varying amounts of interfering substances in leaf extracts tend to mask small changes in the amounts and distribution of the acaricides.

A number of chromatographic systems have been tried to remove interfering substances. The most promising method found was to pass the leaf extract through a concentrated sulphuric acid/celite column. Such columns can be used with various solvents, including petroleum ether, and offer considerable promise in the analysis of the exhaustive extracts of leaves containing traces of acaricides which appear to have penetrated the leaf tissues.

U.V. absorption methods

The methods for the determination of certain residues included some based on U.V. absorption. The absorption spectra of chlorobenzilate, chlorbenside and chlorfenson in ethyl alcohol solution, have been determined and are in good agreement with those published by Gunther and Blinn (1).

Other spectra, hitherto unpublished, are presented here as they may be of interest to other workers—viz., fenson (*p*-chlorophenyl benzenesulphonate) and the oxidation products of chlorbenside, *p*-chlorobenzyl-*p*-chlorophenyl sulphoxide and the corresponding sulphone (*see* Figure 1).

The molar absorptivities for several of the acaricides and related compounds have been determined at the appropriate wave lengths and used to determine residues of the acaricides on glass surfaces in a comparison of rates of loss of the compounds from residual films on inert surfaces.

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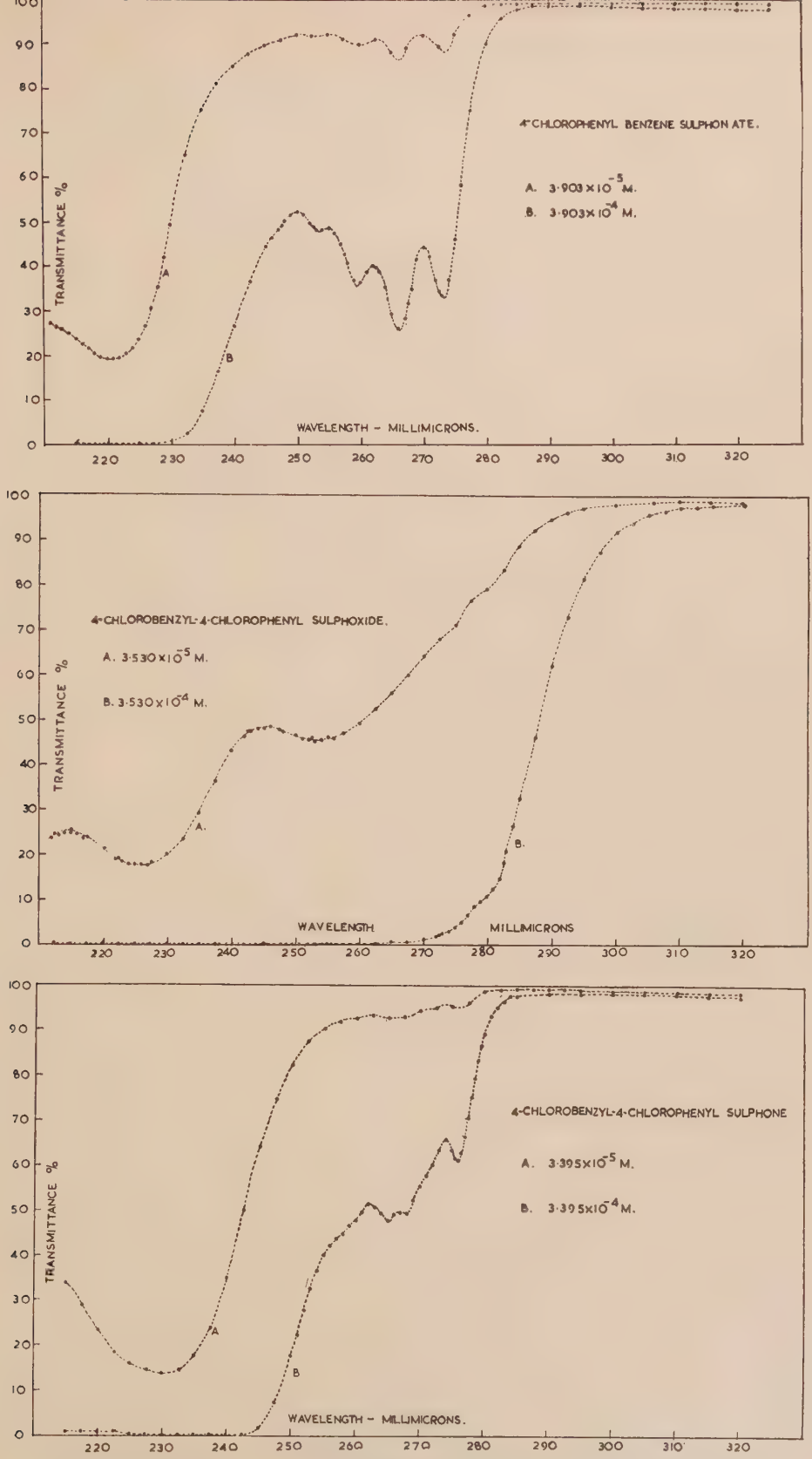

FIGURE 1. Absorption spectra of fenson and the oxidation products of chlorbenside

APPENDIX

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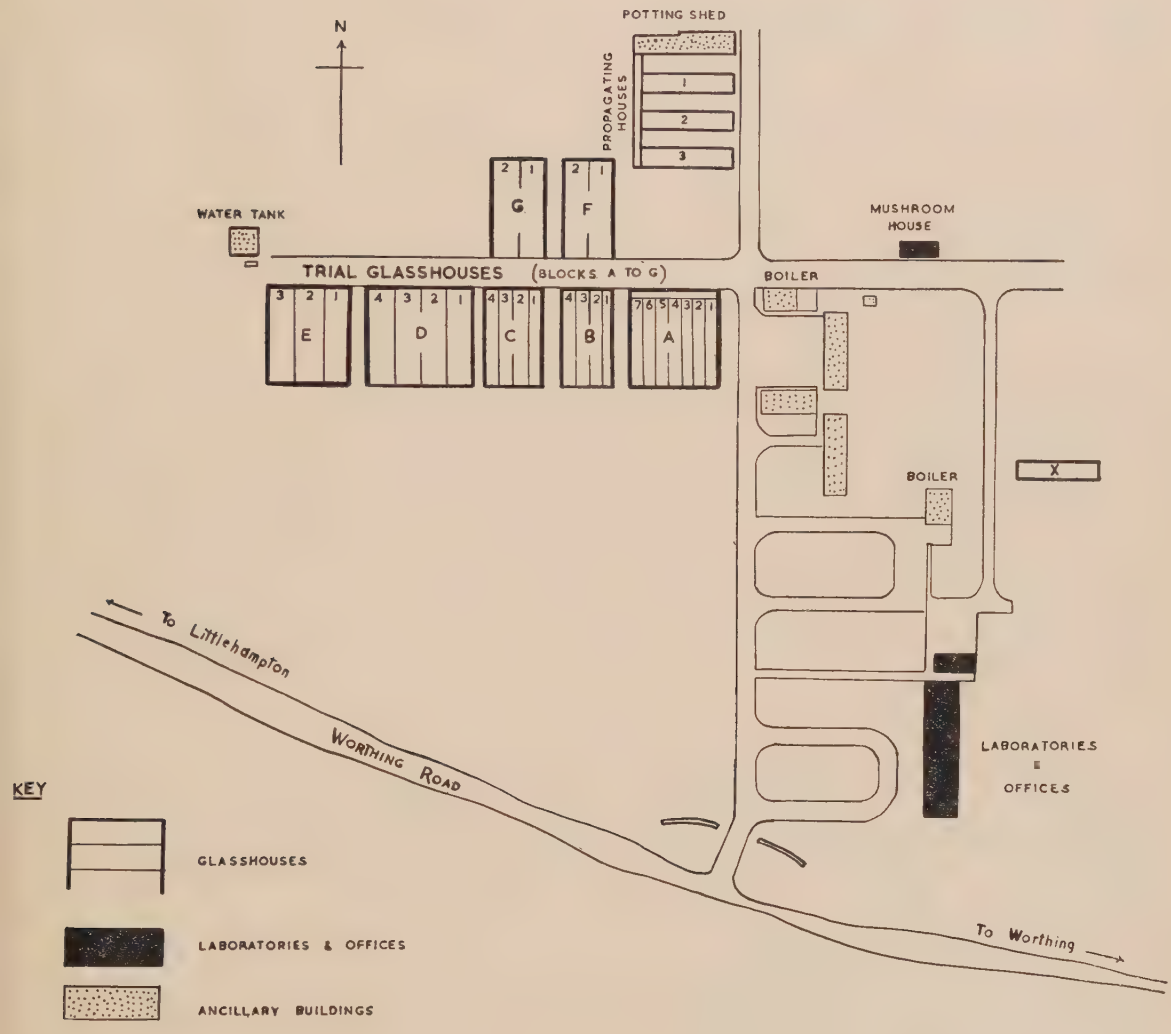

Layout of the glasshouses, laboratories and other buildings

THE JOURNAL OF HORTICULTURAL SCIENCE

THE JOURNAL OF HORTICULTURAL SCIENCE, which is sponsored by the Long Ashton Research Station and the East Malling Research Station, welcomes contributions on horticultural science from Research Institutes at home and abroad. Papers for publication and all communications should be sent to the Editor at East Malling Research Station, Maidstone, Kent.

The current VOLUME 33 (1958) contains papers from both the sponsor Research Stations, from the Glasshouse Crops Research Institute, John Innes Horticultural Institution, National Vegetable Research Station, Scottish Horticultural Research Institute, Ditton Laboratory, Wye College, and the Grassland Research Institute. There are also papers from the United States and the Netherlands. The list of subjects is again very wide; there are papers on the culture of fruit and vegetables in the open and under glass, and several on the incidence and control of diseases and pests. Of particular interest to growers of glasshouse crops are the papers dealing with various aspects of tomato growing; others include fruit-tree rootstocks, and the effect of radio-active phosphorus on stock-scion relationships; parthenocarpy in apples and pears, root development and plant nutrition. The influence of soil moisture on crops in the open and under glass is a notable feature.

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